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1 June 1984

China Report

ECONOMIC AFFAIRS

ENERGY: STATUS AND DEVELOPMENT--XXVIII

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CHINA REPORT
ECONOMIC AFFAIRS
ENERGY: STATUS AND DEVELOPMENT -- XXVIII

CONTENTS

MEETING ENERGY GOALS REQUIRES RETHINKING OF INVESTMENT POLICY

HK190345 Shanghai SHIJIE JINGJI DAOBAO in Chinese 26 Mar 84 p 6

[Report: "Lin Hanxiong, an Authoritative Figure in Energy Circles, Sets Forth Ways To Raise Funds to Develop China's Energy Industry"]

[Text] The strained situation in energy supply and transportation constitutes a major factor that is holding back the development of China's economy. Because the construction of a large-scale energy project needs a lead time of 8 to 10 years, only 12 years are left in the current century for such a project to yield returns on the investment. Recently, this reporter interviewed Lin Hanxiong, president of the China Energy Research Society, on the issue of raising funds for the construction of energy projects within the next 12 or 13 years.

This authoritative figure in energy circles pointed out: As far as China's energy resources are concerned, estimated reserves are large, but verified reserves are far smaller. In all industries which consume energy, the average consumption per unit of production is high, but the average consumption per worker is low. To a certain extent, the above facts constitute a major reason for the serious shortage of energy in China in recent years, and this state of affairs is not expected to change in the near future. Doubling energy output by the end of this century is an arduous task which will not be easily fulfilled. He pointed out: According to the relevant quarters' rough estimate, funds required for energy development and conservation in the coming years up to the year 2000 will amount to the total investment in the national economy during the 28 years between 1952 and 1980, or the total accumulation in the period of the Sixth and Seventh 5-Year Plans. How can we raise such a huge amount of funds in the next 12 or 13 years? How can we lower the investment in the energy sector? These are not only questions facing energy departments, but also are questions concerning all industries and trades in China.

Lin Hanxiong said: In the past, funds for energy development were all borne by the state. It seems that this method can no longer raise sufficient funds for future energy development.

Our economy suffered several major setbacks after 1958, and a serious imbalance developed among various economic sectors. Now, all industries and trades have yet to be reinvigorated and they all require financial support from the state. The enormous demand for development funds has gone far beyond

the financial capacity of the state. When distributing its investment, the state is apt to "attend to one sector while failing to meet the needs of another sector," and the investment policy of the state is apt to lean toward some industries. In the last 2 years of the Sixth 5-Year Plan and in the period of the Seventh 5-Year Plan, the state will have to raise the proportion of energy investment by about 10 percent over the present level.

At the same time, in order to open up more channels for raising energy funds, it is necessary to encourage localities to use more funds in energy development and encourage the coastal areas in eastern China, which are poor in energy resources, to invest in the interior areas, which are rich in these resources, and to run joint ventures in conducting energy development and producing energy-intensive products. Therefore, it is necessary to adopt suitable policies to ensure reasonable returns for the investors and to decide on reasonable methods of distributing products and calculating output value to inspire localities' enthusiasm. For example, in the energy-poor east coast areas, there are still some untapped water power resources which may generate more than 13 million kilowatts of electric power. It is necessary to instruct relevant provinces and cities to invest in building hydropower stations. Electric power generated by these stations can be left at the disposal of the investors without being included in state supply plans. Even large-scale hydropower stations can be built on the basis of state-local joint ventures. The expenses for resettling residents in the affected areas and for compensating for the loss of inundated land can be taken as part of the locality's investment. The economic benefits of the power stations after they are put into operation can be shared between the state and the locality according to their investment proportions. It is necessary to strictly control the capital construction projects. Those under the technological standards of the 1970's must not be allowed to be built. Resolute measures should be adopted to stop the building of enterprises which cannot acquire a guaranteed energy supply. Thus, funds can be saved and used to develop energy industries, transportation facilities, and scientific and educational undertakings.

The energy industry itself has a great ability to yield profits and accumulate funds, and we should make full use of this to develop the energy industry and strengthen the self-reliance capacity of this industry. At the same time, it is necessary to establish a state energy development fund to ensure the stable supply of funds for the development of the energy industry. Extra taxes should be levied on the use of limited energy supply in some fields so as to make up the deficiency in funds for energy conservation. It is also necessary to increase the amount of low-interest loans for energy development and conservation. Since the adoption of the responsibility system in the countryside, peasants have had more money. If need be, we can consider the method of issuing "energy development shares" among the peasants to encourage private investment.

The energy industry has good conditions for absorbing foreign capital. After careful study of the feasibility of each proposed project, we can invite foreign investment in the development of coal mines, oil fields, hydropower stations, and nuclear power plants. If necessary, we can issue special energy bonds at home or abroad.

Lin Hanxiong stressed: At present, the most effective way to remedy the deficiency in energy funds is to lower the construction costs of energy projects, shorten their construction period, and make them yield returns quickly. It is inadvisable to start many large-scale energy projects at the same time; instead, it is necessary to use the methods of systems engineering to coordinate the timing and sequence of the beginning of the proposed projects so that our limited funds can be used in key fields. The huge strip mines with a production capacity of tens of millions of tons of coal and the large-scale hydropower or thermal power stations with a generating capacity of tens of millions of kilowatts of electricity require long construction periods, large investments, and high technology. If these projects are started too late, they will not help realize our strategic objective in the current century and will just become an "encumbrance" to the improvement of investment results. However, if they are started in haste, they are likely to experience periodic standstills because of shortages of funds, materials, and equipment, or as key projects which require priority treatment, they may lead to the suspension of some minor energy projects which can yield quick returns. In all cases, it will be hard to ensure satisfactory returns on the investment in general terms.

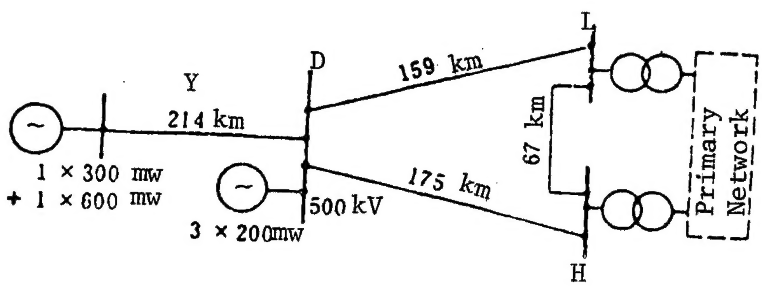
CSO: 4013/149

SELECTION OF 500KV TRANSMISSION LINE PROTECTIVE DEVICES FOR NORTHEAST GRID

Beijing DIANLI JISHU [ELECTRIC POWER] in Chinese No 9, 5 Sep 83 pp 1-5

[Text] I. Current Status of the Grid and Basic Ground Rules for Selecting Transmission Line Protection Schemes

The 500 kV transmission lines of the northeast Power Grid are about to go into operation; the initial network configuation is shown below:



Initial Network Configuation of the Northeast Power Grid

The power load of the Y and D regions is very light; the initial 500 kV network is composed of the transmission lines of power plants whose output will account for a major portion of the total network capacity. When these lines are interrupted due to breakdowns or repair, the system will lose a major power source and therefore suffer severe power shortage. For example, if line DL breaks down, and at the same time line DK is interrupted due to error in the protective relays, the primary network will lose more than 1 million kW of power: clearly, the consequences will be very serious.

In order to meet the requirements of network interconnections and operations, we have established the following ground rules in selection relay protection schemes and coincidence gating devices for the initial 500 kV transmission line of the Northeast Power Grid:

(1) effective technical measures must be taken to prevent error in the protective device:

(2) effective technical measures must be taken to ensure successful operation of the coincidence gating device;

(3) the reliability and speed of operation of the protective device must be increased.

It is also necessary to establish basic ground rules for implementing the selected protection scheme and for designing the logic circuitry for the protective device and the automatic gating device. In other words, consistent with safety considerations, problems concerning the reliability, speed, sensitivity, and selectivity of the protective device should be properly addressed.

In order to ensure safety and reliability of the protection device and the automatic coincidence gating equipment, we should utilize as much as possible the fully-tested protective device and its components and circuits developed for the 200 kV network; and devote our energy to solving any new problems associated with the 500 kV network.

As shown in the diagram, most of the initial 500 kV transmission lines are rather long; therefore, using the short-circuit current level as a basis for comparison, its capacitance current is greater than that of the 220 kV lines. The amplitudes of the high-frequency transient in the short-circuit current are correspondingly higher, its lowest frequency is closer to the operating frequency, and the attenuation time of the transient component of the short-circuit current becomes longer. Because a high-voltage impedance is installed in parallel with the rather long transmission lines, when a short circuit occurs in the bus, it produces a dc component, and the ratio between the lowest end current level and the maximum allowable load current will be notably decreased. The use of capacitor type voltage transformer also produces rather large transient errors.

Currently, the only communications channels available for the 500 kV transmission lines are the ground-relative type power lines.

II. Selection of the Protective Device and the Automatic Coincidence Gating Device

(A) Selection of the Main Protective Device

Based on the above ground rules, we shall now discuss the possible candidates for the main protective (fast-acting) devices.

1. Electric current phase comparison type series protection

The main feature of this type of protection is that it uses electric current only: It is simple and reliable, and has been used extensively in China's 220 kV transmission lines. However, when used in longer 500 kV transmission lines, a voltage feedback circuit must be introduced to compensate for the effect of capacitance current, and the high-voltage parallel impedance may drop out during operation. We have very little experience with this type of compensation. Furthermore, this type of protective device is slow-acting; when single phase coincides with a faulty circuit, or when there are defects

in the incomplete phase operation, the device suffers delayed action. Consequently, it should not be used as the main protective scheme.

However, due to its unique advantages, it is still a good main protective scheme in a short 500 kV transmission line. The performance requirements in this application are essentially the same as those for the 220 kV lines.

2. Directional distance series protection with allowable tripping

This is a main protective scheme which is feasible in medium and long transmission lines, but there is little operational experience with this scheme. Its main disadvantage is that when there is a short circuit at the outlet of the line, the trip signal may be blocked, causing accelerated tripping of the circuit breakers in the adjacent line. Therefore, it must be supplemented by other types of main protective schemes in order to ensure simultaneous tripping of the circuit breakers on both sides of the transmission line. Maximum safety can be achieved by using the under-range allowable tripping scheme, but it requires a protective grounding distance element with good resistance properties and with no over-range problems. This type of element must be tested in the 200 kV lines before they are accepted as mature technology.

3. Directional distance series protection with locked tripping

After extensive comparisons of the protective schemes, the direction distance series protective scheme with locked tripping was selected as the main protection for the initial 500 kV transmission lines of the Northeast Power Grid. The reasons for its selection are as follows:

(1) By using a distance element as a fault discrimination element, it is easy to avoid closed gating or coincidence gating under an empty load and the adverse effects of capacitance current caused by malfunctions in an adjacent circuit of two parallel lines or in a circular network. This is in fact the weakness of series protective schemes such as electric current phase comparison or negative sequence power direction comparison.

(2) It is easy to avoid the effects of different harmonics of short circuit current.

(3) When using over-range protection, one can use grounded directional distance elements to perform the dual function of directional discrimination and fault phase discrimination, so the entire protective system is independent and complete.

(4) The demand on channel capacity is small.

(5) Fast-acting negative sequence or zero sequence incremental elements can be used to activate and transmit the locking signal, so that it is possible to keep the action time of the entire system to less than 30 msec without sacrificing safety.

(6) By conducting protection tests of the entire system, including the channels before actual operation, it is possible to verify the safety of the locking procedure when breakdowns occur outside the region.

(7) One can fully take advantage of the experience gained in designing, testing and operating the serious protective schemes for the 220 kV network including the inter-phase distance protective scheme, the distance phase selection elements, and the direction comparison scheme.

This type of locking procedure has the following disadvantages:

(1) When the protective device is activated due to external operation or malfunctions, the transmission line will lose its main protection. But the probability of repeated breakdowns at different regions is extremely small; furthermore, for frequency-induced grounding problems, the back-up protective device which uses a zero sequence current protective scheme would still be effective.

(2) In the case of system oscillation, the line will lose its high-speed protection; then the problem becomes one of selectively eliminating the faults. In order to minimize damage to circuits and equipment, it is desirable to isolate the faulty component as quickly as possible, but one must be careful not to remove a circuit by mistake during system oscillation.

(3) Faulty protection on one side of the line would make the entire protective system ineffective. There are two possible faulty protection situations. One is caused by a poor quality protective device on one side, which can be corrected by stopping the locking signal when a trip pulse is transmitted by any protective device. The other occurs when a single-phase ground with large grounding resistance breaks down, causing malfunctions in the directional distance element on the far side of the faulty point as well as malfunctions on the close side of the faulty point due to the arrival of the locking signal. This situation can be corrected by simply connecting the zero sequence current cut-off element in parallel with the locking signal receiving point.

(B) Selection of Back-up Protective Device

Since most of the breakdowns in 500 kV transmission lines are due to grounding problems, in addition to using the 3-segment interphase directional distance protection as back-up protection against short circuit breakdowns, we also considered using the multi-segment zero sequence current protection device (which is simple and reliable, has long cut-off range, can protect against high resistance grounding problems, and does not drop out during system oscillation) as the back-up protection against grounding problems.

(C) Selection of Automatic Coincidence Gating Device

For the logic circuit of the automatic coincidence gating device, we should adopt the fully tested circuit used in the 200 kV network, but a careful study should be conducted in selecting the phase selection elements.

As pointed our earlier, the main protective device uses the fully tested directional distance element as the phase selection and direction discrimination elements. In order to achieve single phase coincidence gating, it is prudent to select a different phase selection element which is compatible with the zero sequence current protective device. This will provide complete and independent double protection against grounding problems.

On three of the Northeast 220 kV lines, elements based on abrupt changes in phase current difference were used as post acceleration starting elements for incomplete phase operation during the single phase coincidence gating process. Based on statistics of protective actions over the past 7-8 years and the corresponding breakdown records, analysis showed that all the recorded actions were correct. Therefore, we decided to use these new phase selection elements. The unique features of these elements are as follows:

(1) In the case of single phase malfunctions, the phase selection elements in the two unaffected phases are not activated, hence the resulting phase selection is accurate. It can also be used as the post acceleration starting element when malfunctions in the two phases recur during the incomplete phase operation of the single phase coincidence gating process.

(2) In the case of multi-phase breakdowns, the elements of all three phase current differences can be activated simultaneously: thus any tripping protective device can be connected to this type of phase selection circuits.

(3) The protective device is composed entirely of current circuits, which are simple and reliable.

(4) It is not affected by load current as long as imbalance conditions are avoided; hence higher sensitivity can be achieved.

(5) The absolute value of the faulty current is independent of the ground resistance; hence its action is very reliable.

(6) The magnitude of the output transient component is related to the initial phase angle of the faulty current, which causes certain dispersion on the starting value; in addition, to ensure reliable phase selection of the protection tripping in the grounded time delay section, it is necessary to rely on zero sequence current starting element to maintain action.

(7) When the system undergoes oscillation with very short periods (during the later stage of oscillation), the abrupt change element of the reaction current difference may be activated during oscillation. When it is used as the post acceleration starting element for the single phase coincidence gating process, the "Safety and Stability Guidelines for Electric Power Systems" published by the Ministry of Water Resources and Electric Power, requires that at the time of successful single phase coincidence gating, the system must be in synchronous and stable operation, i.e., the occurrence of asynchronous oscillation is not allowed. For the sake of safety, one may consider eliminating post acceleration of incomplete phase operation after successful coincidence and complete phase operation is resumed.

(D) Auxiliary Protection

In view of the unique advantages of the phase current cut-off elements, they can be used as auxiliary protection for the circuits.

III. The Implementation of Double Protection

For a relatively short transmission line, one can consider using both the locked tripping directional distance series protection and the electric current phase comparison series protection. However, as pointed out earlier, for a longer line during the initial stage only locked tripping directional distance series protection can be used; therefore, it must be able to provide complete protection against any potential malfunctions or abnormal operating conditions that may arise in practice.

In order to meet the various functional requirements of the protective devices, and to provide better protection by using semiconductor circuits (the problem of interference rejection in the secondary circuits of the 500 kV transformer station must be further investigated), it is desirable to implement double protection on the initial 500 kV lines by using two main protective schemes which consist of electromagnetic elements and semiconductor elements. However, when using both schemes simultaneously, the following problems must be addressed:

(1) Error in any protective unit will trip the circuit breaker; hence special measures must be taken in the design to prevent error in the protective devices.

(2) In achieving single phase coincidence gating, it is necessary to ensure successful coincidence gating even if any one protection unit fails at the first malfunction, and to prevent false movement due to post acceleration disorder in coincidence gating.

(3) Direct connection between the two protective devices should be eliminated as much as possible; each device should be able to operate independently, and its circuits should be simplified in order to improve its safety and reliability, and to facilitate maintenance and repair.

IV. The Structure and Main Features of the Circuit Protection System

(A) Basic Structure

The circuit protection system is composed of the following protection schemes: multi-segment zero sequence current protection, phase current cut-off protection, composite coincidence gating with phase selection elements based on abrupt changes in phase current differences, 3-segment inter-phase directional distance protection, and locking type series protection which uses the inter-phase directional distance elements of the 3d segment and three additional grounded directional distance elements.

(B) Main Features of the Locking Type Series Protective System

1. It uses negative sequence current incremental elements as the logic starting element and locking signal generating element for the entire protective system, and uses grounded and inter-phase directional distance elements for signal termination. Signal termination can also be accomplished by tripping pulses transmitted by any protective device.

2. The grounded directional distance elements can be tripped directly through independent zero sequence current cut-off elements.

3. It uses instantaneous action zero sequence voltage circuits with time delay reset (its setting depends only on the locking action of the inter-phase distance elements under single phase ground conditions; it has a very narrow range of protection with high sensitivity) to open the 3-phase tripping circuit of the inter-phase directional distance element; phase selection tripping is accomplished by means of grounded directional distance elements.

4. By using the gating time difference between the circuit breakers on both sides (which can be guaranteed by different settings between the two coincidence gating times), and by checking for electric current in the test circuit (indicating that the main circuit breaker is closed) and for simultaneous action of the distance element to determine if fault coincidence has occurred or if the fault has disappeared, it is possible to achieve instantaneous post acceleration of the coincidence gating. If it is diagnosed that faulty condition still exists in the line, then the three phases are cut off immediately on this side and the signal is terminated in order to ensure that instantaneous post acceleration tripping takes place on the other side. If it is determined that the faulty condition has disappeared, the protective device will continue to transmit locking signals in order to ensure that even when the potential angles on both sides of the power source are swung open, coincidence of the protective devices on both sides will still be successful.

5. It uses the phase current difference abrupt change elements of the coincidence gating device to achieve instantaneous post acceleration when faulty condition recurs in the non-faulty phase during the single phase coincidence gating process; it is removed when the circuit resumes full phase operation.

6. In order to prevent misjudgment in direction caused by 3-phase short circuit in the bus circuit, the protective device relies on the memory of the directional distance element to transmit a locking signal at the starting element, and automatically inserts a 100-msec receiving reset time delay (allowable tripping) approximately 40 msec before an error occurs in the directional distance element, thus achieving selectivity with the instantaneous protection of the adjacent circuit. This approach can simultaneously solve the following problems: When the opposite outlet is grounded via high resistance, continuous action is maintained without affecting high-speed tripping when faults occur within the region. It also takes care of the problem of direction reversal when faults occur outside the region. During the transient period of the inter-phase distance protection, it cuts over to the 2d segment time delay tripping approximately 40 msec after the starting element is activated.

7. A leading phase voltage is introduced in the polarization circuit of the grounded directional distance element as an auxiliary polarization quantity. For example, the polarization voltage of phase A is chosen to be $U_A - j\ 0.25\ U_C$ in order to achieve correct direction when two-phase and single-phase grounding of the bus circuit occur. In the case of a long transmission line with heavy load, the signal is terminated by activating the directional distance element and the zero sequence current (or impedance) element simultaneously in order to achieve correct direction discrimination when two-phase short circuit occurs in the bus.

8. In order to avoid direct interconnections between the protective devices, we make use of the relative positions of the operating levers of the circuit breaker-operated circuits and the connecting points of the tripping position relays to allow individual protective devices to achieve stabilization of single-phase or three-phase tripping states, and to close different coincidence gating post acceleration circuits.

(C) Technical Requirements on the Protective Device and Its AC Elements

1. The Chinese-built LB-500 current mutual inductor has 6 coils, of which 4 TB_1 and TB_2 coils used in the protective devices have load rating of 20 volt-amp and 15 volt-amp respectively. It has the advantage of secondary rated current of 1 amp. By considering the allowable load of the secondary cable circuit and the present manufacturing standards, the rated loading of the current circuits of the protective devices are chosen as follows:

(1) less than 10 volt-amp for electromagnetic type inter-phase distance protection locking type series protection;

(2) less than 6 volt-amp for electromagnetic type multi-segment zero sequence current protection, phase current cut-off, and composite coincidence gating devices;

(3) less than 10 volt-amp for semi-conductor full protective system.

2. Under any fault condition phase angle, the action time of locking type directional distance series protection must be less than 30 msec.

3. Stability of the action time of various short delay time elements of the logic circuits (particularly electromagnetic type protection).

4. Performance indices of the ac current elements: sensitivity and transient overload capability of the dc and high-frequency transient attenuation component response in the fault current; action and recovery time characteristics; stability of actionvalues; power consumption of the elements.

5. Performance indices of the distance elements: in order to prevent error caused by irregular voltages introduced by the secondary circuits or by the transient residual voltages of the capacitance type voltage mutual inductor when multi-phase short circuits occur in the bus, the minimum action voltage is required to be no less than 1 volt, in addition to other routine requirements.

6. Performance indices of phase current difference abrupt change elements: allowable changes in the action values under different fault initial angles; action time and recovery time; no action when the period of system oscillation is 0.25 sec and the oscillation current is 4 times the rated current; power consumption of the elements.

7. Performance indices of zero sequence voltage elements: action time characteristics.

V. Doing the Groundwork

To ensure safe and reliable operation of the 500 kV transmission lines, we must do the groundwork in the following areas:

1. A detailed and complete analysis of the operation of the protective devices under various abnormal and fault situations should be carried out.

2. To verify the analysis results, complete simulation tests under actual conditions should be performed.

3. The new protective device should be installed and tested in a 220 kV line with numerous faults in order to gain practical experience with the device. The abnormal behavior during operation should be analyzed to determine its cause and to take appropriate corrective measures.

4. The field test personnel and operators should become familiar with the characteristics and capabilities of the new protective device; their full cooperation is required to ensure safe and reliable operation.

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CSO: 4013/21

POWER NETWORK

BRIEFS

NEW XINJIANG POWER LINE--Urumqi, 25 Apr (XINHUA)--A 207-kilometer power transmission line, the longest in Xinjiang, went into operation today. The line runs from Urumqi, capital of the Xinjiang Uygur Autonomous Region, eastward to Qitai County. Electricity is now available to four counties and five state farms which previously depended on small hydroelectric stations and diesel engines for power supply. [Text] [OW251550 Beijing XINHUA in English 1453 GMT 25 Apr 84 OW]

CSO: 4010/80

KUWAITI DELEGATION VISITS SHAXIKOU, LOAN AGREEMENT EXPECTED

Fuzhou FUJIAN RIBAO in Chinese 1 May 84 p 1

[Text] The delegation from the Kuwaiti Fund for Arab Economic Development [KFAED] wound up its on-side appraisal at the Shaxikou hydroelectric power station and a loan agreement is to be signed in Beijing in the next few days.

The Shaxikou hydroelectric power station is the second major construction project to make use of a KFAED loan. Technical representatives of the Ministry of Water Resources and Electric Power's Huadong Survey and Design Institute and the Min River Hydroelectric Construction Bureau briefed the KFAED delegation on the overall situation regarding the construction of this hydropower station. While inspecting the Shaxikou construction site, the Kuwaiti experts were delighted to see that the 1000-meter cofferdam for the excavation of the dam's foundation had already taken shape.

In a cordial atmosphere, the Chinese and Kuwaiti delegates held productive exchanges on matters concerning the construction and loans. After the meeting was concluded yesterday afternoon, officials of the Ministry of Water Resources and Electric Power told this reporter that the Kuwaiti experts felt that the design of the Shaxikou hydropower station was basically sound, that construction preparations were proceeding quickly and satisfactorily, and that the design units and construction personnel were proving equal to the task.

The KFAED delegation will depart today from Fuzhou to visit Quanzhou and Xiamen, after which it will fly to Beijing.

CSO: 4013/168

400,000-KILOWATT CASCADE STATIONS COULD BE BUILT ON DAZHANG XI

Fuzhou FUJIAN RIBAO in Chinese 19 Apr 84 p 1

[Excerpt] Fujian's Dazhang Xi could support cascade power stations with an installed capacity of more than 400,000 kilowatts. This was brought up during a briefing given by officials of the Huadong Hydroelectric Survey and Design Institute for the leadership of the Provincial Party Committee and Government on the evening of 18 April. The planning and survey work for the comprehensive development and use of Dazhang Xi is now being stepped up.

The source of the Dazhang Xi is near Daiyun Shan in Dehua County, Jinjiang Prefecture, and from there it flows through Yongtai County. With a total basin area of 4,685 square kilometers, it is the largest tributary on the lower Min Jiang. It is fairly close to Fuzhou, Putian, and other cities. If used comprehensively for the generation of electricity, shipping, aquatic products, etc., the river would be a tremendous boon to the growth of industry and agriculture in the above-mentioned cities and counties. In 1980 and 1982, the provincial hydropower department's survey and design institute and the survey and design brigade of the Min Jiang hydroelectric engineering bureau conducted surveys of power resources and came up with a development scheme. But due to manpower and material constraints, and the 10-year period of turmoil, only a small part of the hydraulic resources of the Dazhang Xi have been exploited.

Since 7 April of this year, based on the two previous surveys, additional surveys have been made. Xu Baili, the assistant head of the Huadong Survey and Design Institute of the Ministry of Water Resources and Electric Power, Senior Engineers Sun Yegao and Cao Zhengzhi, and other engineering and technical personnel (22 persons in all), braved heavy spring rains to negotiate hills and mountains to make on-the-spot surveys of the numerous possible dam sites along the banks of the Dazhang Xi. With cooperation and assistance rendered by provincial and city authorities and with support from the concerned organs of the two counties of Yongtai and Dehua, they spent 10 different days gathering much first-hand information, coming up with a preliminary plan to further accelerate planning and development.

CSO: 4013/163

PROGRESS SAID GOOD ON LONGYANGXIA, ANKANG PROJECTS

Beijing RENMIN RIBAO in Chinese 8 Apr 84 p 1

[Text] By the end of March, 547,000 cubic meters of concrete had been poured on the dam of the Longyangxia Hydroelectric Power Station, currently the nation's highest dam; the acceptance rate for engineering quality was 100 percent, of which 62 percent was rated "excellent."

The Longyangxia Hydroelectric Power Station is a major state construction project. The station's dam has a design height of 178 meters, which, when completed, will create the nation's largest man-made lake (24.7 billion cubic meters).

At work round the clock here, the cadres and workers of the 4th Engineering Bureau of the Ministry of Water Resources and Electric Power assure quality work by strictly following construction standards. During the 6-month-long winter construction season, they erected thermal shelters, burned coal and charcoal, and installed electric heaters and hot-air blowers to provide additional heat when pouring the dam, thus preventing the formation of ice in the concrete.

Since the flow of the river was blocked late in 1983, progress on the Ankang Hydroelectric Power Station, a major national construction project, has been smooth. As of the end of March [1984], 630,000 cubic meters of earth and rock had been removed in building the dam's foundations, and 580,000 cubic meters of concrete had been poured, representing respectively 90 percent and 58 percent of the dry season construction plan.

The Ankang Hydroelectric Power Station is located on the Han Jiang [sic], a major tributary of the Chang Jiang. Because of the unusually heavy flooding along the Han last year, blocking of the river was delayed by 2 months and dry season construction time was shorter than in former years. On top of this, geological conditions in the area are complex and large-scale landslides and cave-ins on the banks have severely hampered construction. Pooling their know-how and strength, the more than 13,000 workers engaged on the construction site are overcoming tremendous problems in an all-out effort to complete the dry season construction tasks before the onset of the wet season in mid-May.

CSO: 4013/155

ADVANCED TECHNIQUES USED IN DESIGN OF BAISHAN

Beijing SHUILI FADIAN [WATER POWER] in Chinese No 11, 12 Nov 83 p 22

[Text] The Northeast Survey and Design Institute of the Ministry of Water Resources and Electric Power has made significant contributions to the construction of the Baishan hydropower station and to the development of China's hydropower technology by carrying out any analytical calculations and scientific experiments, and by using a series of new techniques, new structures, and new equipment in the design of the Baishan hydropower station. Some results of using advanced techniques are summarized below:

1. By taking advantage of Baishan's favorable terrain and geological conditions, a gravity-arch concrete dam was designed and built. This dam is currently the tallest three-core circular dam in this country. Its midsection has a radius of 320 m and each side has a larger radius of 770 m. The length of the arch is 676.5 m with a maximum central angle of 80° 21'. The maximum dam height is 149.5 m and the width of the dam is 9.0 m on top and 63.7 m at the base; the arch to height ratio (s/h) is $\sim$ 4.525 and the thickness to height ratio (B/h) is $\sim$ 0.426. In the design, an electronic computer and the three-term load adjustment method were used to perform dam stress calculations under different load conditions. The result was a more advanced geometric dam design.

2. The all-underground power house system of the hydropower station is the largest in this country. The maximum excavation width of the power house is 25 m; it is 52.75 m in height and 121.5 m in length, and the amount of excavation was 372,000 m^3. The entire system consists of groups of overlapping and intersecting chambers centered around the power house; jet anchor support structures were used extensively, and the total area is 57,200 m^2.

3. The three water inlets on the right side of the underground plant system are arranged in radiating and overlapping pattern. Such an arrangement not only improves the stability of the rock structure at the inlets and simplifies treatment, it also reduces the amount of excavation and poured concrete at the inlets. As a consequence, construction time was shortened and the total investment was reduced by 2 million yuan.

4. The overflow from the main dam has a drop differential greater than 100 m, and a flow speed of 40 m/sec; the maximum flow rate is 13,200 m^3/sec. In order to minimize the erosion of the river bed downstream by flood water, the design

used an interleaved arrangement of overflow holes and deep holes, so that the energy of the water stream will be dissipated in all three directions.

5. The rear section of the overflow dike head of the main dam is equipped with aeration pits, so that air bubbles in the high-speed water stream can escape to avoid air corrosion of the dike surface.

6. The high-pressure power tunnel is made of reinforced concrete or plain concrete with a short steel steening. The three high-pressure power tunnels at the Baishan hydropower station have diameters ranging from 7.5 m to 8.6 m, and are 753.6 m in total length. The flow rate used for power generation is over 300 m^3/sec, and the maximum internal water pressure is 15 kg/cm^2. Only a 45-m section near the power house is made of steel plates; the remaining sections are made of steel-reinforced concrete or high-pressure plain concrete prestressed structures.

7. Baishan Hydropower Station has three 300,000 kW hydraulic turbine generators, currently the largest in the country. They weigh over 800 tons and are very difficult to manipulate by cranes using conventional steel-reinforced concrete beams. Consequently, steel "I" beams are used in this design; they have a span of 10.5 m and can carry loads of 1,000 tons with a maximum wheel pressure of 70 tons. This design represents China's highest standards.

8. For the first time, a high-volume injection pump was used in domestic hydropower stations. The generator units at the Baishan hydropower station requires water supply at the rate of 1,200 m^3 per hour. By using new techniques which are still in their infancy, China's first high-volume injection pump was designed and built. Also, by using river branches as sources of water supply, the available water for power generation upstream is preserved; this can result in annual savings of electric energy of approximately 200,000 kWh. The injection pump shares the same water head as the power-generating operation (from high-pressure steel pipes); its pressure rating is 18 kg/cm^2, its nozzle diameter is 52 mm, its outlet diameter is 300 mm, and the unit flow rate is 800 m^3/hr.

9. In order to minimize the amount of space occupied by the switching station of the underground power house, new technologies in high-voltage electrical equipment were imported from abroad to be used in China's first 220,000-volt sulfur hexafluoride sealed composite electric device. Industrial tests show that its technical performance meets and in some cases exceeds international standards.

10. Construction of the largest hyperbolic-arch bridge in the mountains of northeast China. Approximately 700 meters downstream of the Baishan hydropower station, an attractive and structurally stable hyperbolic arch bridge spanning 80 meters over the Di'er Songhua Jiang was constructed. The central pier of the bridge was built using a large floating well; the main arch structure was installed using the new single-cable suspension technique. Since its completion and opening for traffic in November 1977, the bridge has held up very well under conditions of the 75°C temperature differential in the Changbai Shan region.

In addition, other advanced techniques used in the design include: scattering communication system for remote control of the power stations; controllable silicon self-opening drive magnet system to ensure safe operation of the generator units, as well as noise control, interim illumination, and air drop systems for improving the working conditions of the underground power house.

3012
CSO: 4013/56

BRIEFS

ERTAN FEASIBILITY STUDY APPROVED--In February of this year [1984], the feasibility study for the Ertan Hydroelectric Power Station was approved by the State Council. When completed, the station's installed capacity of 3 million kilowatts will play a major role in developing the mineral deposits of the Panzhihua Mines and in the industrial buildup of the southwest. Since the latter part of 1983, the Chengdu Survey and Design Institute has worked up plan after plan, implementing Comrade Hu Yaobang's directive to "cut construction costs, select the optimal plan, and shorten building time." Engineering plans for the dam's configuration, stability studies on the shoulders of the dam, and designs for the underground power house have gone through a number of reviews, being progressively simplified and improved. [Summary] [Chengdu SICHUAN RIBAO in Chinese 10 Apr 84 p 1]

CSO: 4013/167

THERMAL POWER

PROGRESS, QUALITY SAID GOOD AT XIAOLONGTAN NO 2 POWER PLANT

Kunming YUNNAN RIBAO in Chinese 13 Jan 84 p 2

[Article by Shi Weikang [2457 4850 1660]]

[Text] To capitalize on the winter construction season to reinforce its operations, the 4th Provincial Construction Engineering Company decided to speed up work on the Xiaolongtan No. 2 Power plant. Last December, it poured over 6000 cubic meters of concrete, a project worth 1.05 million yuan.

The No. 401 and No. 403 construction teams of the 4th Provincial Construction Company are in charge of pouring the foundations of the coal and water supply systems of the Xiaolongtan No. 2 Power Plant. Since the quality and pace of their work have a direct bearing on all subsequent work, the leaders of the 4th Company found out upon in-depth investigations that weather-wise, Kaiyuan is best suited for construction, especially for high-quality concrete work, because the winter there is comparatively mild and dry. After careful consideration, the company leadership revised the construction schedule and ordered from other construction sites 23 small automatic dump trucks and two new concrete mixers to reinforce the Xiaolongtan No. 2 Power Plant building site. It also changed from one shift a day to two shifts in 24 hours to allow the workers to take turns to rest but keep the equipment running continually. To tighten the economic responsibility system, it breaks down the work load of each link and passes them to the teams and groups in order to synchronize raw materials transport, concrete mixing, and pouring without any work holdups or down-time. The company's pre-fab plant and supply division are responsible for supplying the cement required by the construction teams.

Company leadership and those in charge of construction made prompt changes in construction management procedures to allow them to take turns to be on duty at the various links of the construction to supervise the progress and quality of the work at the construction site in order to strengthen the construction organization. Take the preparation of concrete for example. To attain high-quality concrete works and

cut down the cost of construction, the company leader who is on duty at the work site must see to it that the sand and gravel are weighed and measured before mixing and that the poured concrete is covered with straw mats to prevent cracking.

The strengthened construction management has helped speed up the construction. The No. 401 team has basically completed the foundations of the four big coal chutes it was responsible for. The clear water basin and the inclined-pipe settling basin completed last December by the No. 403 team have created more favorable conditions for subsequent construction. The jobs completed last December by the two teams represent the highest monthly record of the 4th Company.

5360
CSO: 4013/99

BRIEFS

TAIZHOU SECOND PHASE BEGUN--Work on the second phase of the Taizhou Power Plant in Zhejiang Province began today [15 March]. According to design specifications, the Taizhou Power Plant will have a total installed capacity of 500 MW, with construction to be carried out in two phases. In the first phase, two 125,000 kilowatt generators were installed and became operational in 1983. They have already produced 1.08 billion kilowatt-hours of electricity. The second phase calls for the installation of two more 125 MW generating units which are slated to become operational in 1985 and 1986 respectively. [Text] [Hangzhou ZHEJIANG RIBAO in Chinese 16 Mar 84 p 1]

ANHUI POWER PLANT CONSTRUCTION--Hefei, 1 May (XINHUA)--Construction of a large steam power plant started today in Huainan City, East China's coal mining center. The Pingwei Power Plant will have a generating capacity of 600,000 kilowatts by 1987 when it is installed with the country's first generating unit of that capacity now being manufactured with imported technology. [Text] [OW011130 Beijing XINHUA in English 1118 GMT 1 May 84 OW]

CSO: 4010/80

UPGRADED TRANSPORTATION NETWORK TO BOOST SHANXI COAL SHIPMENTS

OW281911 Beijing XINHUA in English 1502 GMT 28 Apr 84

[Text] Taiyuan, 28 Apr (XINHUA)--The state will invest 850 million yuan (about 425 million U.S. dollars) this year in the construction of key coal mines in Shanxi Province, according to Governor Wang Senhao.

The figure was a 54.5 percent increase over last year, Wang told the second session of the province's 6th People's Congress which closed here today.

The funds will be used to sink or enlarge 24 coal mines to produce an additional 40 million tons a year, and build six coal washing plants with a total annual capacity of 10.9 million tons, he said.

One hundred sixty-two locally-run mines will also be expanded this year to produce an additional 22 million tons annually, he said.

Shanxi, China's largest coal producer, cut 157.4 million tons last year, over 22 percent of the nation's total.

A 500,000-volt power transmission line between Datong and Beijing will go into operation this year, the governor said. Six generating units with a combined capacity of 1.1 million kilowatts will also go into operation in three power plants by 1985.

Construction will continue on a 630-kilometer railway line between Datong and the port city of Qinhuangdao in Hebei Province, Wang said. The double-track, electrified railway is designed to carry 100 million tons annually.

Double-tracking and electrification of another five trunk railway lines will be speeded up this year to increase shipments of coal out of Shanxi.

Four trunk highways will be completed by 1985 linking Shanxi with Hebei, Shandong and Henan provinces. The roads will boost coal shipments to the three areas from the present 10 million tons to 23 million tons a year, Wang said. More than 1,400 heavy-duty trucks will be imported for coal transport.

The governor urged local governments to ensure completion of 15 national top-priority projects in Shanxi.

CSO: 4010/80

COAL

SHAANXI DILEMMA: HEAVIER OUTPUT, OVERSTRAINED RAIL SYSTEM

HK111047 Xi'an Shaanxi Provincial Service in Mandarin 1130 GMT 9 Apr 84

[Excerpt] Leaders of the provincial CPC committee and the provincial government have decided to take measures to solve the problem of overstocking of coal. The cadres of the coal mines have been greatly inspired.

This year, the production situation on our province's coal front is excellent. The state production quota for the first quarter was overfulfilled. Production unified distribution coal mines increased markedly. Of them, the Tongchuan Mining Bureau, whose increased output was the highest, overfulfilled its quota for raw coal production for the first quarter by 140,000 tons and its gross output reached a record 1.84 million tons.

While the coal mines greatly increased production, transport capacity was limited, resulting in serious overstocking of coal. Although the Xi'an Railroad Bureau transported 200,000 tons more of raw coal than in the same period last year, the contradiction between production and transport was still not mitigated. To date, the Tongchuan Mining Bureau has kept 510,000 tons of raw coal long in stock. The Hancheng, (Hubai), and (Changhe) mining bureaus also have kept a large amount of coal in stock. The overstocking of large amounts of coal has brought about very great difficulties to the normal production in the coal mines. According to statistics, only the overstocking of raw coal in the Tongchuan Mining Bureau has caused a wasteful loss of over 1.5 million yuan to the state.

Confronting this difficult situation, (Shi Jiaoqi), secretary of the Tongchuan Mining Bureau CPC Committee; and (Chen Guanxing), director of the bureau, rushed to Xi'an to report the emergency. Leading comrades of the provincial CPC committee and the provincial government turned their attention to the situation. They held many meetings to listen to the reports of the Tongchuan Mining Bureau and studied the problem of the overstocking of coal. Leaders of the provincial CPC committee and the provincial government concluded:

1. The railroad transportation departments must strengthen regulation and direction, try to make enough rolling stock available to meet needs, strive to tap potential, and move more coal quickly.

2. It is necessary to give full play to the transport role of roads. It was initially decided that materials transported a distance of under 50 km must be transported on roads and no railroad transport will be arranged for them. Regarding the materials transported 50 to 100 km, some of them must be transported on roads, and that where necessary, passenger transport by railroad from Tongchuan to Xi'an can be diverted to transport by motor vehicle so that railroads can be used to transport coal, thus increasing the amount transported. We than make motor transport lighten the burden of railroads.

3. According to the storage quota and to their conditions, the seven power plants under the Northwest Power Administrative Bureau can further increase the amount of storage and must do a proper and good job in organization to improve loading and unloading work. They must attempt to store more coal to lighten the pressure on the coal mines.

4. Coal mines must stress the quality of coal and must reduce the amount of raw coal power so as to increase the utilization ratio of railroad cars and minimize waste in transport capacity.

5. It is necessary to organize well the transport of coal out of the province.

All units concerned are vigorously implementing these five specific measures.

CSO: 4013/150

COAL

ACCELERATING DEVELOPMENT OF LIAONING'S LOCAL MINES

Shenyang LIAONING RIBAO in Chinese 14 Jan 84 p 2

[Article by He Ao [0149 0277]]

[Text] Coal is the major source of energy for the industries of Liaoning, and yet the annual output of the coal mines in the province can meet only 50 percent of the need. The increasing demand for coal in the wake of the development of the national economy has made the shortage of coal supply a marked weak link in the economic development of province. While working to increase the output of the state's unified distribution coal mines, we must also accelerate the exploitation of the local coal mines, an important way to bridge the gap between supply and demand of coal in Liaoning.

The numerous local coal mines scattered all over the province can be very easily exploited locally for local use at a much lower cost. They can play an important role in improving the layout of the coal industry, easing up energy shortage, accelerating the development of local industry and agriculture, boosting the collective economy, and providing coal for urban and rural household consumption. The local coal mines which have grown quite rapidly in the past few years include two operated by the province, 41 by the cities and counties, over 500 by the communes and production brigades, and 197 by the masses with their pool of financial resources. In 1983 they produced more than 6.1 million tons of coal, up by 12 percent from 1982. The increase, trailing other provinces, is still not enough to meet demand.

What are the local coal resources of Liaoning? Is it possible to produce enough coal to keep pace with the cost advanced mines of the country? The answer is yes. Liaoning is rich in coal resources and has a considerable production and construction base. With the support of the state's unified distribution mines and the backing of a powerful machine industry, the local coal mines no doubt will develop at a faster pace. The key point is to mobilize all sectors--naturally and within economic laws--to run the mines. At present, the following must be done well:

1. Geological prospecting must be done in advance. Since there must be coal underground before mining can take place, any capital mine construction must be preceded by thorough geological prospecting of the coal fields to provide geological data needed to prepare a prospectus, run a feasibility study (a

technical assessment), and make an initial plan. According to the mine construction program projected for the next 7 years, there are about 300 million tons of coal reserves available for exploitation. But due to inadequate geological prospecting, there are not many known reserves other than those already tapped to warrant additional mine construction. This calls for more prospecting to identify the reserves to justify additional mine construction. The Bureau of Geology of the Dongmei Coal Corporation has done a great deal of geological prospecting of local coal mines in Liaoning. Prospecting local coal mines accounted for 17 percent of its prospecting of the coal fields of the entire province in 1983. This has accelerated the geological prospecting of a number of major mining centers, including Jinbucun in Shenyang and Xuwangzi in Liaoyang. It has also gone beyond the scope agreed upon to help arrange 46,000 meters of prospecting projects for 1984, 36 percent of the prospecting for the whole province. It has indeed made positive contributions to the development of local coal mines. By the same token, the local coal mines should have their own small geological prospecting teams adequately equipped to complete supplementary prospecting of existing working coal mines.

2. Formulate construction programs to build new mines as planned. Unlike other industries, coal mining faces the problem of retiring old, declining mines and building new ones, which takes time. The construction of new mines should be planned so as to maintain sustained and uninterrupted normal production. There are 12 pairs of local coal mine shafts under construction with an estimated annual output of 1.14 million tons. To complete the construction of these mines for profitable operation before 1985, it is necessary to shorten the construction time, upgrade their engineering quality, cut down the construction cost, and promote "construction by contractors" in order to realize the "four responsibilities and two guarantees." The four responsibilities include budget estimates, construction timetables, quality, and the beginning of construction. The two guarantees are the guarantee of construction material and the guarantee of construction investment. The program for the construction of local coal mines in Liaoning within the next 7 years calls for 35 pairs of new shafts with a projected annual output of over 3.6 million tons. These less costly but economically profitable small mines can be constructed quickly. The problem is lack of funds. In addition to funding by the state and the province, we may solicit investment by the big enterprises to help develop the local mines which can provide the coal required by the big enterprises themselves. This indeed is a great potential worth tapping.

3. Work to develop coal mines run by communes and production brigades. In the past few years, both the State Council and the provincial government have adopted a number of programs to promote local interest in coal mining, including subsidies for coal mining losses, subsidies for tunneling and payment of arrears, short haul subsidies, collection of maintenance fees, unification of production and marketing, and supply of flour and rice to the miners. The output of the local coal mines increased considerably in 1982 and 1983, registering a new increase of 600,000 tons. In February 1983, leading comrades of the CPC Central Committee asked for a more lenient policy on developing the small coal pits of the production brigades. The State Council thereupon approved a report on measures to develop small coal mines prepared by the Ministry of Coal Industry, and stimulated the interest of the cities and counties, especially the rural governments, the production brigades, and the masses in pooling funds to operate mines. The number of coal mines run by collectives and production brigades has

grown from 304 at the end of 1982 to 502, and those funded and run by the masses now total 197 with more than 3000 miners. In 1983, coal mines run by the production brigades turned out a total of 3.2 million tons of coal, 300,000 tons of which were produced by mines jointly operated by the masses. Of course, the drive to develop local mines has run into new situations and new problems, such as the need to extend and deepen the pits, the need for more effective pumping and ventilation, and the need to withdraw accumulated funds to finance both simple and expanded reproduction. There are also problems of mining accidents due to inadequate safety measures, high salaries, and the recruitment of miners. All these must be examined and studied for proper solutions to ensure healthy growth.

4. Strengthen management, tap potential, increase output, and upgrade economic effectiveness. A coal mine is a mobile underground factory where work is done under the threat of such natural disasters as flood, fire, gas, coal dust, and underground pressure. Safety measures should be continually revised and supplemented to upgrade emergency capabilities. Strive to cut down the number of incidents and eliminate as far as possible the serious accidents. Strengthen the management of those areas concerning geological structure, methods of exploitation, and mining procedure to ensure standard mining and production safety. The departments of coal industry at all levels should improve their internal structure with reinforced technical staff. Any locality which still lacks a safety supervision department should establish one with a full technical staff. The coal mining safety departments on and above the county level should exercise dual leadership, and the coal industry departments of the cities and counties should be mainly responsible for safety supervision. The comrades of the coal industry departments should go regularly to the work sites to investigate and examine new situations and problems which accompany the development of the local coal mines, sum up the new experience, and use representative cases of success to guide the work.

Liaoning's existing shafts still have lots of potential. There are 13 pairs of shafts with a projected output of 1.16 million tons, but they produced only 700,000 tons in 1983. These mines should strive to replenish all the production links, strengthen the management of their technology, upgrade mechanization, and increase as much as possible the per unit output and tunneling in order to achieve the projected production volume. Liaoning has 11 pairs of shafts due for technical transformation. Their current capacity is 610,000 tons but will reach 1.83 million tons after transformation. These mines, rich in reserves and close to transportation facilities, should push for technical transformation to tap their potential and increase their production. Once these are done, Liaoning's local coal mines will grow fast and contribute immensely to industrial and agricultural production and to the livelihood of the people.

5360
CSO: 4013/102

BRIEFS

SHANXI 1ST QUARTER OUTPUT--Output of coal of the local coal mines in Shanxi Province by 26 March was 8,536,00 tons, an increase of 8.89 percent over the same period last year, and they fulfilled the state quota for raw coal production for the first quarter 5 days ahead of schedule. [Summary] [HK090604 Taiyuan Shanxi Provincial Service in Mandarin 2300 GMT 1 Apr 84 HK]

NATION'S BIGGEST DRESSING PLANT--XINHUA, 12 May 84--China's largest and most modern coal and coke dressing plant--Kailuan's Fangezhuang Dressing Plant--officially went into production on 12 May. The Fangezhuang Coal Dressing Plant has a design capacity of 4 million tons of coal a year. The major equipment for the production shops was imported from the Federal Republic of Germany, with the remainder being domestically manufactured. The equipment and technology are quite advanced. From the dressing of the raw coal to the finished product, to loading and shipping--all phases of production are controlled by computer. Following 9 months of trial production, checking, and acceptance, the plant's production capacity and quality have met design requirements. [Text] [Beijing RENMIN RIBAO in Chinese 13 May 84 p 2]

CSO: 4013/167

OIL EXPLOITATION IN SOUTHERN YELLOW SEA BEGINS IN EARNEST

OW131213 Shanghai City Service in Mandarin 1100 GMT 10 Apr 84

[Text] The curtain has been raised on oil exploitation in the offshore areas in the southern part of China's Yellow Sea. According to this station's reporter, the Bohai No 10 drilling rig arrived off Qingdao in the southern Yellow Sea without a hitch today to take part in the drilling of the first of the oil wells to be sunk in the southern Yellow Sea in the joint Sino-British oil exploitation there.

Seven Shanghai companies, which serve offshore oil exploitation, have enthusiastically provided the equipment and supplies needed for the prospecting and extracting operations.

Prospecting has been in full swing since the beginning of April in the three contract areas, which represent the first in the joint oil exploitation between Chinese and foreign companies in the offshore areas of the southern Yellow Sea. Chevron Overseas Petroleum Ltd. and Texaco Orient Petroleum Inc. of the United States, and the Clough Oil Company of Britain have already carried out geophysical prospecting work in their contract areas. The BP Petroleum Development Ltd. of Britain is making faster progress.

For drilling the first oil well in the southern Yellow Sea, public bids were held successively in Guangzhou and Shanghai for over 200 service and supply contracts. The successful bidders so far include 7 Chinese companies, 8 companies which are joint Chinese-foreign ventures, and 22 foreign companies. In addition, 23 service contracts have been signed with Britain's BP Petroleum Development Ltd and the Nanhuanghai Oil Company.

The Shanghai Sea-Petroleum Service General Company, Shanghai Vessel Service Company, Shanghai Helicopter Company, and Shanghai Weather Service Company--all of which are newly established--are among the successful bidders in the first round of international bids held for oil exploitation in the southern Yellow Sea. Thanks to their efforts to give full scope to economic potential in the Shanghai area, take advantage of the technical superiority of the industrial and supply departments, and actively coordinate with concerned units, they have already got all the needed supplies ready in the short period since winning the contract. Currently, they have provided three triple-use vessels for sea operations, one helicopter, and a large quantity of chemical supplies for Britain's BP Petroleum Development Ltd. to sink the first well in the southern Yellow Sea.

The Shanghai Seaborne Petroleum Engineering Joint Company and Shanghai (Haimao) Engineering Service Company--two of the Chinese-foreign joint ventures, which have undertaken the manufacture and repair of offshore oil drilling rigs--will also offer their services in the sinking of the first oil well in the southern Yellow Sea.

CSO: 4013/149

EASTERN CHINA MESOZOIC-CENOZOIC BASINS AND HYDROCARBON OCCURRENCE

Beijing DIZHI XUEBAO [ACTA GEOLOGICA SINICA] in Chinese Vol 57, No 3, 1983 pp 224-234

[Article by Li Desheng [2621 1795 3932] and Xue Shuhao [5641 0647 3185]]

[Text] All of the oil-and gas-bearing basins of eastern China are characterized by Mesozoic and Cenozoic fault-subsidence basins* (Figure 1). Thorough research on the structural and sedimental characteristics of this type of petroliferous basin is useful not only for further improvement of the results of exploration in already-developed basins and similar basins in the surrounding area, but is also very beneficial for the guidance of exploration for hydrocarbon resources on the Chinese continental shelf.

I. The Sedimentary History of Eastern China

The eastern area of China underwent a complex evolutionary history from Protozeroic to Cenozoic times: (Figure 2)

1. Proterozoic--Paleozoic

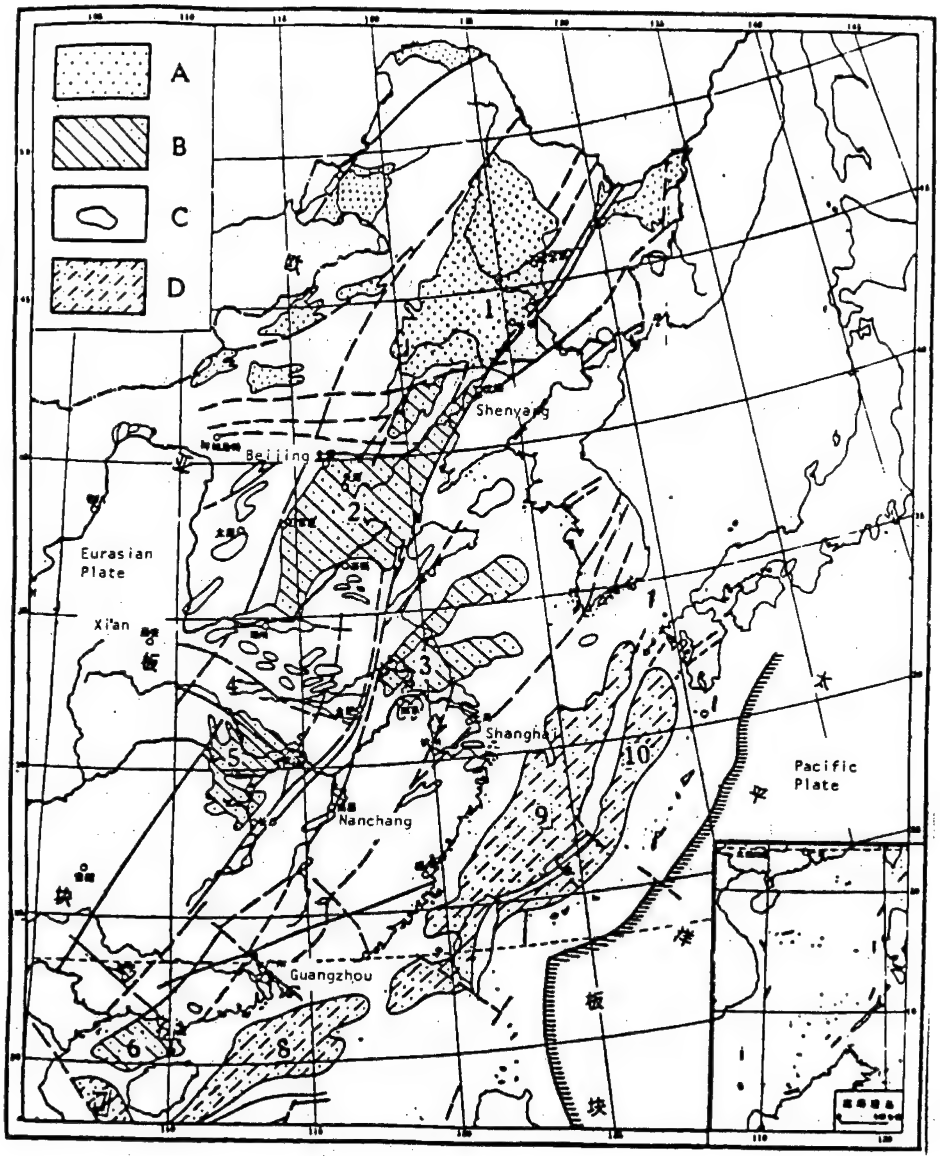
The northeast region developed as geosynclinal deposits of graywacke, slate, limestone, and a large amount of submarine volcanic rock. It was folded upward and emerged as a denudation zone in the later part of the Permian. Vast and thick areas of fungus and algae-rich dolomitic limestone were formed in the northern China region during the Middle and Late Proterozoic. The Cambrian to Middle Ordovician Periods were a stage of stable platform development, and there were broadly-distributed carbonatite sediments. There was a period of denudation from the Late Ordovician to the Lower Carboniferous. From the Middle and Upper Carboniferous to the Permian, it went from coal-bearing deposits on the marine-terrestrial interchange facies to continental facies fluvial and lacustrine clastic rock sediments. Shallow-sea calcareous and argillaceous sediments formed in the southern region from the Late Protozeroic to Lower Palaeozoic eras. The Yangzi platform emerged as dry land during the later part of the Lower Paleozoic. The Jiangnan and Huaxia regions also continued to be folded. There was a broad-scale marine transgression in the Carboniferous and Permian Periods. This commonly formed carbonatite and coal-bearing sediments on the land-sea interchange facies.

*This article does not include the central or southern islands of the South China Sea.

Figure 1. Structural Outline of the Oil- and Gas-Bearing Basins in East China

Key:

1. Songliao Basin
2. Bohai Gulf Basin
3. Northern Jiangsu--Southern Yellow Sea Basin
4. Nanyang--Biyang Basin
5. Jianghan Basin
6. Beibu Gulf Basin
7. Yinggehai Basin
8. Zhujiang Kou Basin
9. Western East China Sea Basin
10. Eastern East China Sea Basin



A. Intracratonic fault-subsidence basins
B. Intracratonic multi-cycle fault-subsidence basins
C. Small-scale intracratonic fault basins
D. Crustal margin fault-subsidence basins

2. Mesozoic

The area was differentiated into dry land in the north and sea in the south during the Permian Era. There were also differences between the eastern and western areas. The major portion of the area to the east of the Taihang Mountains was uplifted and became a denudation zone. The movement of the Yanshan Mountains during the Jurassic Period formed a series of coal-bearing fault

basins. During the Cretaceous Period, the margin of the Asian continent on the outer side of Sikhote [USSR], Hokkaido, and Honshu was in a state of marine transgression. The Songliao Basin was a near-shore lake basin and formed excellent oil-generating mudstone and lacustrine delta deposits. It is also possible that the Bohai Gulf and Yellow Sea regions contain near-shore lacustrine sediments.

3. Cenozoic

During the Paleogene, near-shore lacustrine sediments were widely distributed in the Bohai Gulf, Northern Jiangsu, Southern Yellow Sea, Western East China Sea, Zhujiang Kou [Pearl River Mouth], Beibu Bulf, Yinggehai and other basins. These sediments include important source and reservoir rock systems. There were fluvial and lacustrine facies rudaceous accumulations in the continental region during the Neogene. The continental margin underwent marine transgression at various times after the Oligocene.

II. Structural Types of Petroliferous Basins in Eastern China

Two fault-subsidence basin systems formed in eastern China as a result of plate movements during the Yinzhi and Yanshan periods. One of the systems is a continental fault-subsidence system running through the Songliao Basin, the Bohai Gulf Basin, the Jianghan Basin and extending to the Beibu Gulf Basin.(1) The period of formation was from the Jurassic to the Tertiary. Another near-shore fault subsidence system runs through the Southern Yellow Sea Basin, the East China Sea Basin, the Taiwan Basin and extends to the Zhujiang Kou Basin.

According to data from geophysical exploration and exploratory drilling for petroleum carried out in each of the petroliferous basins of eastern China in recent years, the basins have the following structural properties and formational histories (Figure 3) [not reproduced]:

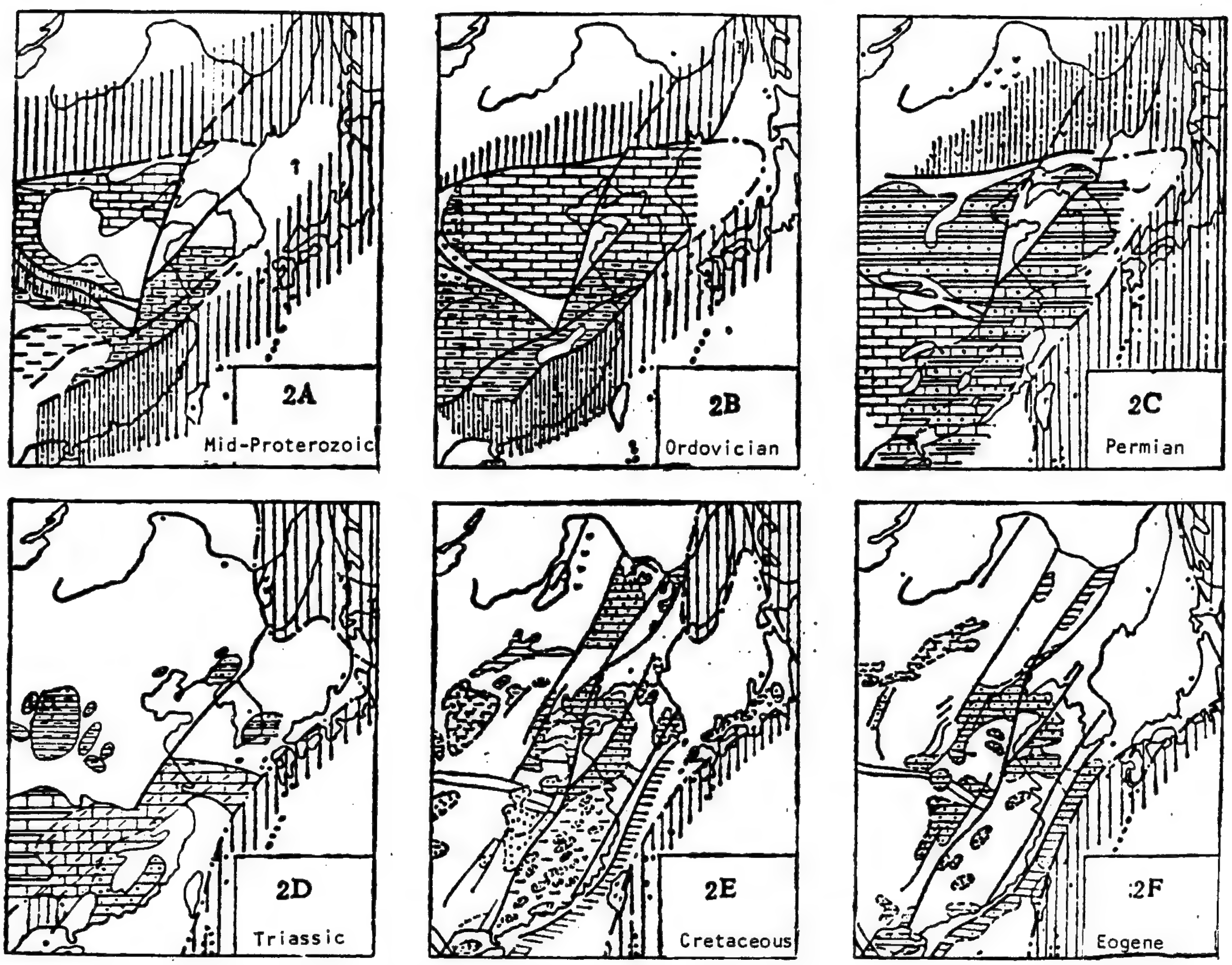
1. Intracratonic fault-subsidence basins

In the example of the Songliao Basin, there is a basement of Hercynian granite.[1] Crustal thickness is about 27-35 kilometers and it is continental crust. The basin underwent a period of faulting in the later part of the Middle Jurassic or the early part of the Later Jurassic. It subsided after the Lower Cretaceous and shrank and was uplifted after the Upper Cretaceous. The main period of folding occurred during the later part of the Lower Cretaceous and formed a series of large anticlinal structures and associated normal faults running in a NNE direction.

2. Intracratonic multi-cycle fault subsidence basins

This type includes the Bohai Gulf Basin, the Northern Jiangsu-Southern Yellow Sea Basin, the Jianghan Basin and the Beibu Gulf Basin. Crustal thickness is about 29-37 kilometers and it is continental crust. The Cenozoic basins are superimposed on the Mesozoic Basins and on fragmented Paleozoic and Protozeroic platforms. There may have been two or more formational stages of alternating faulting and subsidence since the Mesozoic and Cenozoic Periods. The Bohai

Figure 2. Paleogeographic Outline Map of Eastern China and Adjacent Regions



Key:

- Paleocontinental deundation zone
- Marine facies carbonatite sedimentation zone
- Marine facies calcareous mudstone sedimentation zone
- Marine facies clastic rock sedimentation zone
- Littoral coal-bearing clastic rock sedimentation zone
- Marine-terrestrial interchange coal-bearing and carbonatite sedimentation zone
- Marine-terrestrial interchange coal-bearing and clastic rock sedimentation zone
- Carbonatite and evaporite sedimentation zone
- Littoral clastic rock sedimentation zone
- Continental red clastic rock sedimentation basin

Continental dark-colored clastic rock sedimentation basin
Near-shore dark-colored clastic rock sedimentation basin
Small-scale red clastic rock sedimentation basin
Lacustrine and marsh coal-bearing sedimentation basin
Near-shore clastic rock sedimentation zone
Marine sandstone and mudstone sedimentation zone
Marine ooze sedimentation zone
Semi-acidic volcanic rock
Semi-basic volcanic rock
Lithofacies boundary
Main fault zones
Ancient marine-terrestrial boundary

Gulf Basin is an example of this.[2] The Lower Jurassic was a faulting period, while the Middle and Upper Jurassic became subsidence periods. The Lower Cretaceous was a faulting period, while it returned once again to a subsidence period during the Upper Cretaceous. The Paleogene was a faulting period while there was another period of subsidence during the Neogene. The basin has block-fault structural qualities characterized by fracturing movements. The tectonic structure has multiple uplifts and depressions in an alternating sequence. The rounded semi-graben or graben-like depressions formed during the faulting period contain particular sedimentary source areas and sedimentary centers. Subsidence period sediments were laid down on all of the uplifts and within the subsidences.

3. Small-scale intracratonic fault basins.

An example is the Nanyang-Biyang Basin. The basement is a Tongbai Mountain Protozeroic metamorphic rock system. Crustal thickness is 35-37 kilometers and it is continental crust. There was intense faulting in the late Yanshan Period caused by two groups of tension fracturing movements running WNW and NNE.[3] The Upper Cretaceous--Eocene was a faulting period, and the lake basin continued to subside over a large area during the Oligocene. By the Neogene and Quarternary, the basin and the surrounding mountain system had been uplifted together, and there has been obvious erosion of the basin's rim.

4. Crustal margin fault-subsidence basins.

This type includes the western East Sea Basin, the western Taiwan Basin, the Zhujiang Kou Basin and the Yinggehai Basin. Crustal thickness is generally 25-30 kilometers. It is still on the scale of continental crust, but is almost a margin zone. The western East Sea Basin was formed on a foundation of Mesozoic sedimentary and volcanic rock.[4] Paleogene deposits occurred during a faulting period, controlled by tensile-torsional forces. There was a transition to a period of subsidence after the Oligocene, controlled by compressional-torsional forces. Based on interpretation of seismic reflection profiles, there are level strata above the unconformity of the lower part of the Pliocene system. Below

the unconformity is a Miocene system of a series of large anticlinal structural belts in a V-shaped arrangement with a NNE strike.

The basement of the Zhujiang Kou Basin is a Pre-Devonian metamorphic rock system with a large Mesozoic granitic instrusive body. The small Mesozoic basin experienced further fracturing during the Paleogene and expanded into the four large faults of Zhu 1, Zhu 2, Zhu 3 and Qiong Southeast. During the later part of the Oligocene, they formed large lagoons linked to the South China Sea. The four faults continued to subside during the Lower Miocene and the marine transgression intensified. A semi-occluded basin appeared that was bounded on the south by submarine mountains. The basin expanded from the Middle Miocene to the Pliocene. The entire region became a depression deposit and formed an open-sea continental shelf.[2]

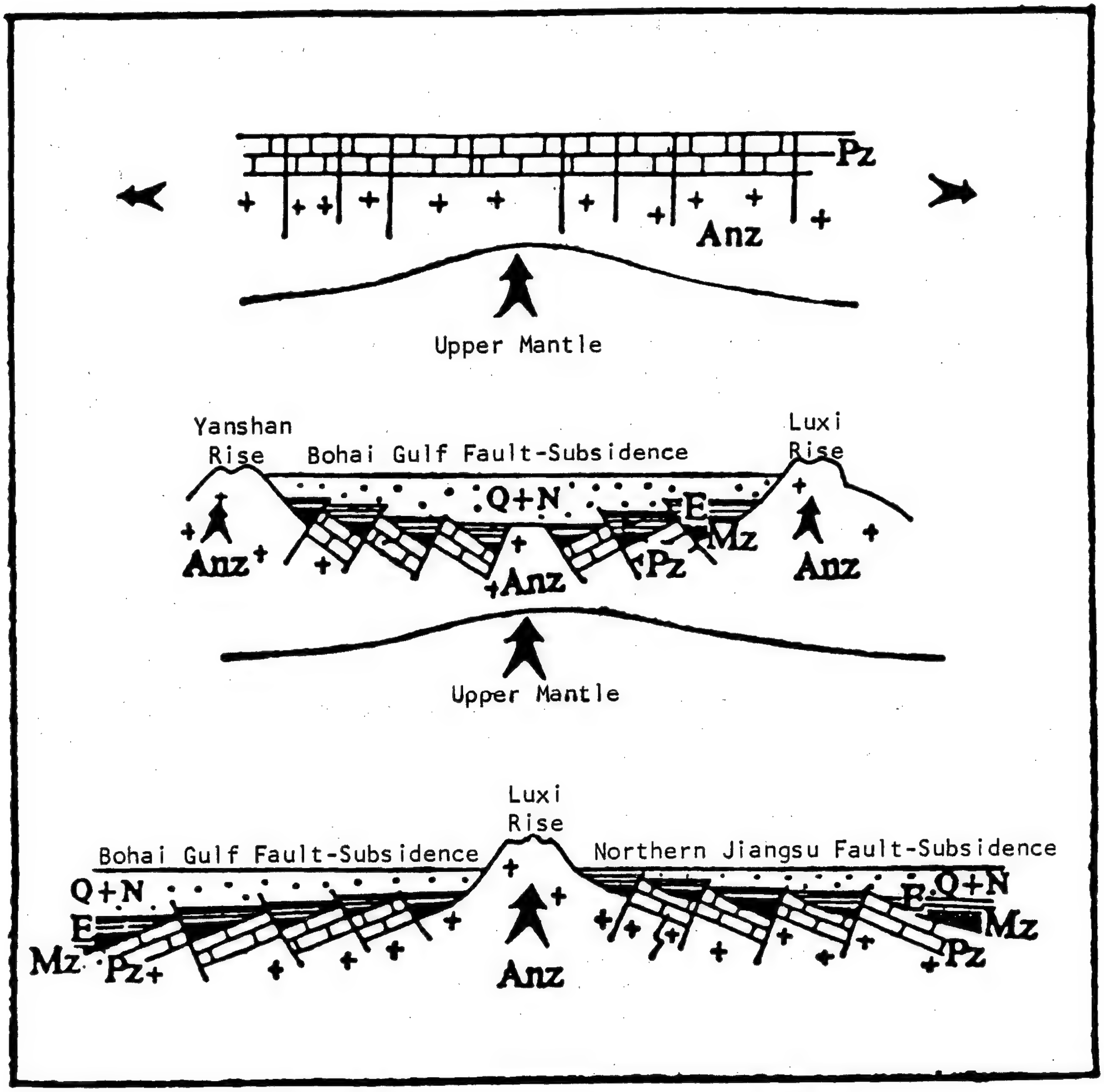
The Yinggehai Basin refers to a Tertiary tensile-torsional basin located between the southwest slope of Hainan Island and the Honghe Rift. According to well drilling data, the foundation of the basin is a Cambrian metamorphic rock system. The very deep descent of the northeast side of the Honghe Rift forms a fault with a northwest strike. It subsided in the Neogene and overrode the southwestern slope of Hainan Island.

III. The Formation Mechanisms of the East China Mesozoic-Cenozoic Basins

Regardless of whether they are intracratonic or epicontinental basins, each of the large fault-subsidence basins of eastern China exhibits relative swelling of the lithosphere.[5] The scale of the swelling of the upper mantle reached several hundred kilometers, roughly equal to the scale of the basins. The corresponding positions on the upper part of the region of large-scale mantle swelling formed Mesozoic-Cenozoic fault subsidence basins. The mantle swelling underwent repeated intervals of formation and disintegration, expansion and contraction, and formed intracratonic multi-cycle fault-subsidence basins. This type of alternating faulting-subsidence activity created conditions favorable to a multilayer presence of oil.

Semi-graben or graben-like formed by tensile faulting developed within all of the intracratonic or epicontinental fault-subsidence basins (Figure 4). Research on several seismic reflection profiles in combination with a large amount of data from exploratory drilling show that all of the normal faults that continued to develop have slow-moving fracture planes. Most of the faults have a dip angle of 30-50 degrees and form a "deck chair-shaped" profile that is steep at the top and gradual at the bottom.[2] Their shape and formation is similar to that of a gravity landslip. When the crust stretched after being subjected to tensile stresses or became thinner, the dip angle of each small block was determined by the change in inclination from the horizontal. During the Paleozoic, Protozeroic, or Pre-Protozeroic Eras, the width of the rift valleys between the blocks reached 2-15 kilometers and the vertical drop could have reached 1-10 kilometers. All of the fault-subsidence basins were filled with Mesozoic-Cenozoic sediments whose thickness was determined by the degree of vertical drop and the average rate of descent of each normal fault.

Figure 4. Formational Mechanisms of the East China Mesozoic-Cenozoic Semi-Graben-Like Depressions



Because they were subjected to a gravitational thrust to the west caused by back-arc expansion of the Okinawa Trench and the Taidong Rift Valley, respectively, the epicontinental fault-subsidences of the western East China Sea and western Taiwan Basins created a series of anticlinal folded structural zones in the western East China Sea Basin and western Taiwan Basin, and they are accompanied by westward-thrusting faults. The Songliao fault-subsidence first underwent extension and subsidence, then shrank and folded. This was related to the westward gravitational trust caused by the later back-arc expansion of the Sea of Japan.

The Eurasian Plate is being moved eastward by the thrust of the Indian Plate, and the Pacific Plate is diving and being subducted to the west. This interferes with thermal convection in the mantle and causes a series of microextensions running in a NNE direction to appear in the east China continental crust. The Paleozoic and Pre-Paleozoic platform underwent block fracturing, and a series of fault basins were formed along the fracture zones which then evolved into large subsidence basins. This caused the eastern part of China to undergo two different evolutionary processes of crustal accretion. One was intracratonic crustal accretion. This created a new series of Mesozoic and Cenozoic fault-subsidence basins which were inlaid within the original fracture blocks and which have become intermixed with them. The second type was crustal accretion at the continental margin. The Pacific Plate underwent several periods of subduction during the active periods of the Yanshan and Xishan. Because of the gradual eastward movement of the subduction zone,[6] the back-arc fault-subsidence basins created in each period led to continual replenishment of the crust at the continental margin.

IV. Sedimentation Patterns in the East China Mesozoic-Cenozoic Basins

The sedimentary buildup in the east China Mesozoic-Cenozoic petroliferous basins was subject to severe restriction and control by the activity of the Yanshan and Xishan:

1. During periods of intense differential movements of the block faults, the tectonic background was a linear structure of alternating uplifts and depressions. This formed a continental rift valley-like sedimentary buildup during the faulting period. An example is the sedimentation pattern of the Liao He fault during the Paleogene[3] (Figure 5-A). There is a major difference in relative elevation between the source area around the fault and the deep narrow lake basin region, and there is a short transport distance. There are coarse, thick belts of alluvial cones or fluvial facies alluvial sandstone bodies on the steep flanks of the semi-graben faults. Biogenic beaches, biogenic clastic limestone or barrier bars occur in the lake and bay positions. Dark-colored mudstone and turbidites are distributed in the deep-water position of the troughs. Some of the faults had buildup of lacustrine evaporites (fine rhythmic strata of (gaoyan) or dark-colored mudstone) under arid or semi-arid conditions. The thickness of the accumulations in the faults can reach 2,000-5,000 meters.

2. A depression sedimentation buildup formed when there was relative calm in extension fracturing forces and the entire basin subsided. An example is the depression sedimentation pattern in the Songliao Basin during the Lower Cretaceous.[4] (Figure 5-B) The area of the lake basin during the subsidence period was larger than during the faulting period, and it covered a series of Jurassic rises and depressions. There were abundant source areas during the subsidence period, and the transport distance was fairly long, so it was easy to form large marginal facies accumulations or delta facies sand bodies (including distributary plain facies and delta front facies). Semi-deep lake facies or deep lake facies mainly of dark-gray mudstone interspersed with some thin layers of biogenic clastic rock, marl or oil shale are found in the center of the lake basin. Because of the abundance of water resources, organic matter and clastic source areas, the subsidence period accumulations in this large type of lake basin can be as much as 3,000-5,000 meters thick.

After undergoing sedimentary buildup during fault-subsidence periods, all of the east China continental Mesozoic-Cenozoic petroliferous basins now have alluvial plan facies or marsh plain facies as the end result of the basins.

3. After undergoing sediment buildup during periods of faulting and subsidence, the Mesozoic-Cenozoic petroliferous basins on the continental shelf along the Chinese coast received semi-occluded sea or open-sea sediment buildup from the Upper Oligocene or Lower Miocene to the Pliocene or Pleistocene. There were regional rises in global sea levels, which caused seawater transgression on the continental shelf of southern and eastern China. This submerged several of the major continental faults and subsidences from the earlier periods. A large amount of silt was transported by the ancient Honghe, Zhujiang, Changjiang, and Huanghe river systems. The silt poured into the nearshore basins and formed several large-scale prograding delta deposits which continued on out to the continental slope.

The marine transgression period begin relatively early in the Zhujiang Kou, Yinggehai and Beibu Gulf basins. The following sediment buildup sequence occurred from north to south beginning in the Upper Oligocene and continuing to the Miocene:

--alluvial plains, fan delta rudaceous rock facies

--branching alluvial and deltaic plains, beach barriers (or offshore bars) and deltaic frontal edge facies

--intertidal or lagoon facies neritic mudstone, sand bars, carbonatite platforms (or biogenic reefs)

--abyssal or semi-abyssal fine-grain sandstone, mudstone, submarine fans, submarine valley fill, submarine landslides and turbidites (such as the open-sea sedimentation pattern of the Zhujiang Kou Basin during the Pliocene; (see Figure 5-C).

Figure 5-A. Eogene Sedimentation Patterns in the Liao He Fault

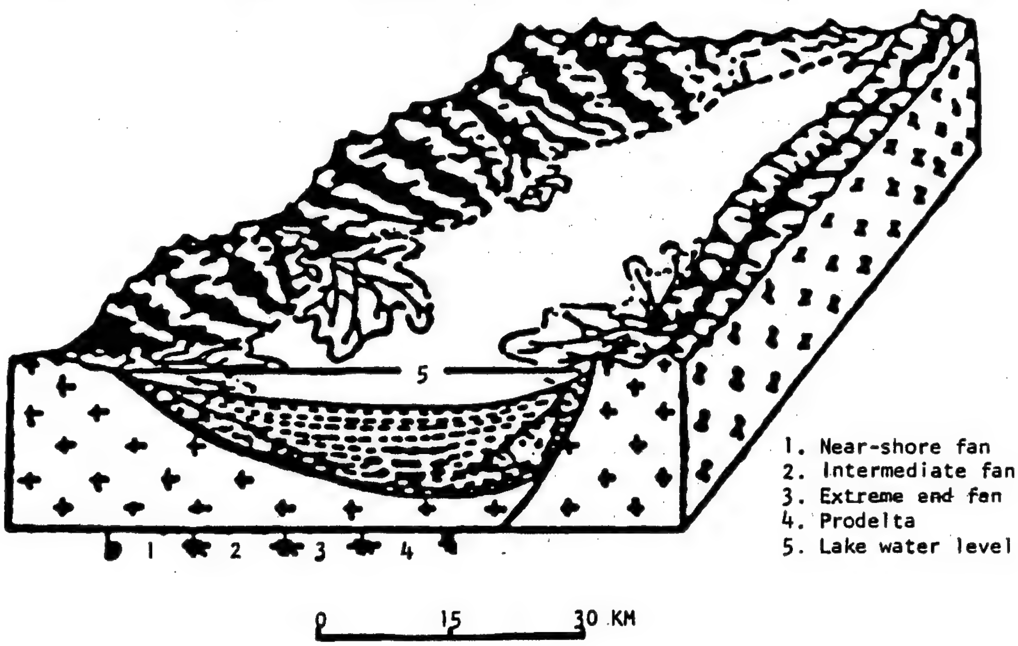


Figure 5-B. Lower Cretaceous Sedimentation Patterns in the Songliao Depression

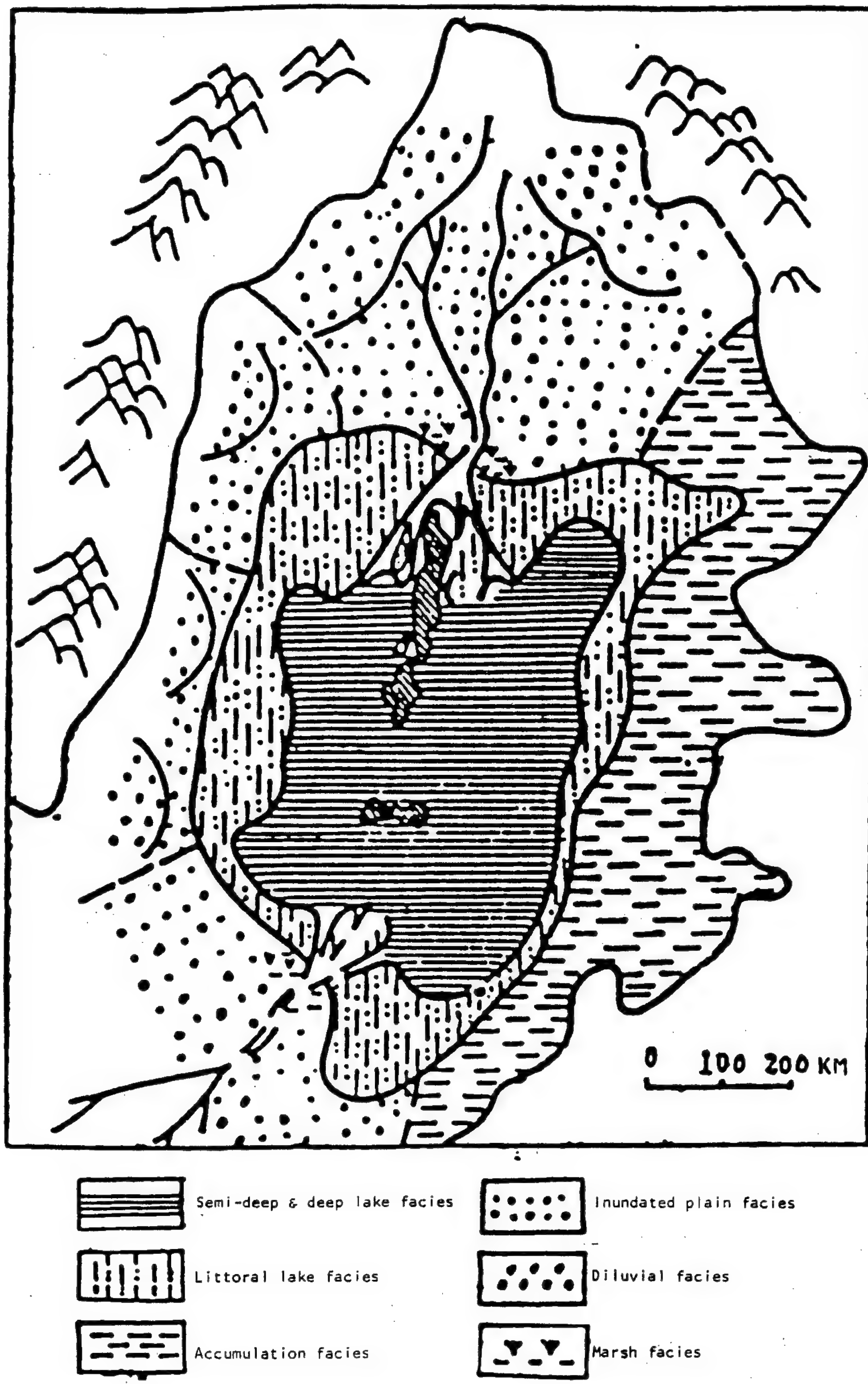
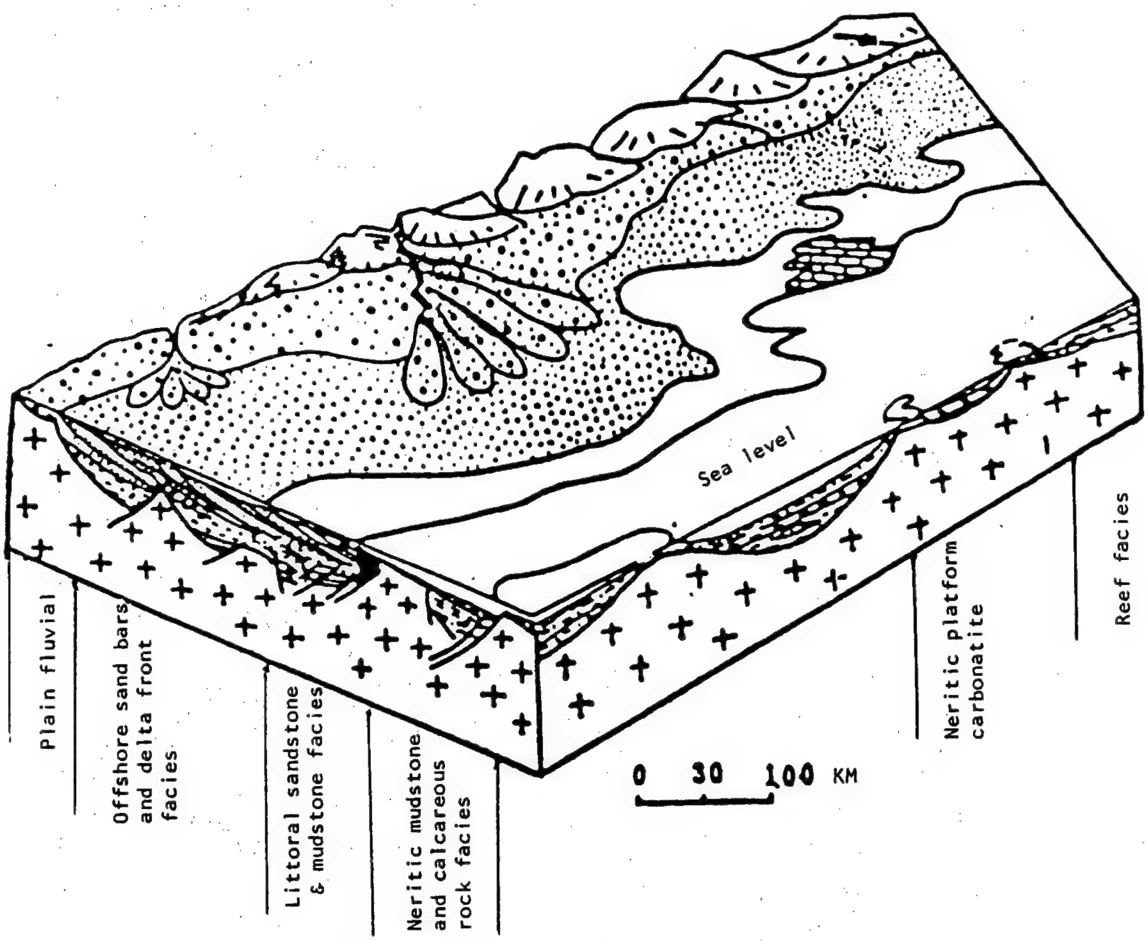


Figure 5-C. Pliocene Open-Sea Sedimentation Patterns in the Zhujiang Kou Basin



The marine transgression of the Yellow Sea, western East China Sea and Bohai Gulf basins occurred relatively late. The seawater transgression did not begin until the Pliocene or Pleistocene, and formed the following sedimentation build-up sequence from west to east:

--alluvial plains, fan delta rudaceous rock

--land-sea interchange facies sandstone, fine-grain sandstone and mudstone

--neritic facies fine-grain sand, mudstone, submarine fan sand and submarine valley fill accumulations.

V. Oil and Gas Distribution in the Mesozoic-Cenozoic Basins of East China

The already-developed continental oilfields of eastern China are distributed within the Songliao Basin, Bohai Gulf Basin, Nanyang-Biyang Basin, Jianghan Basin and Northern Jiangsu Basin. A chart of the longitudinal profiles of vaporized gas strata of each petroliferous basin is shown in Figure 6.

The different structural conditions and sedimentation types are interrelated, and they form different types of abundant and long-exploited oil and gas reservoir traps in the eastern China area.

1. Structural trap gas and oil fields. There are four known types:

1) Dome anticlinal traps. Examples are the gigantic daqing oilfield and the Fuyu Oilfield in the Songliao Basin. The reservoir rock is Lower Cretaceous sandstone.

2) Rolling anticlinal traps. An example is the large Shengtuo Oilfield in the Bohai Gulf Basin. The reservoir rock is Oligocene sandstone.

3) Draped anticlinal traps. An example is the large Gudao Oilfield. The reservoir rock is Miocene conglomeratic sandstone and sandstone.

4) Salt anticlinal traps. An example is the Wangchang Oilfield in the Jianghan Basin. The reservoir rock is Oligocene sandstone.

2. Stratigraphic trap oil and gas fields. There are four known types:

1) Monoclinal traps. An example is the Shuguang Oilfield in the Bohai Gulf Basin. The reservoir rock is Oligocene sandstone.

2) Upper-incline tapering stratigraphic sand traps. An example is the Shuanghe Oilfield in the Biyang Basin. The reservoir rock is Oligocene conglomerate or conglomeratic sandstone.

3) Shoestring sand body traps. An example is the sandstone body oil deposit of the Chunhuazhen River Channel in the Bohai Gulf Basin. The reservoir rock is Oligocene sandstone and conglomeratic sandstone.

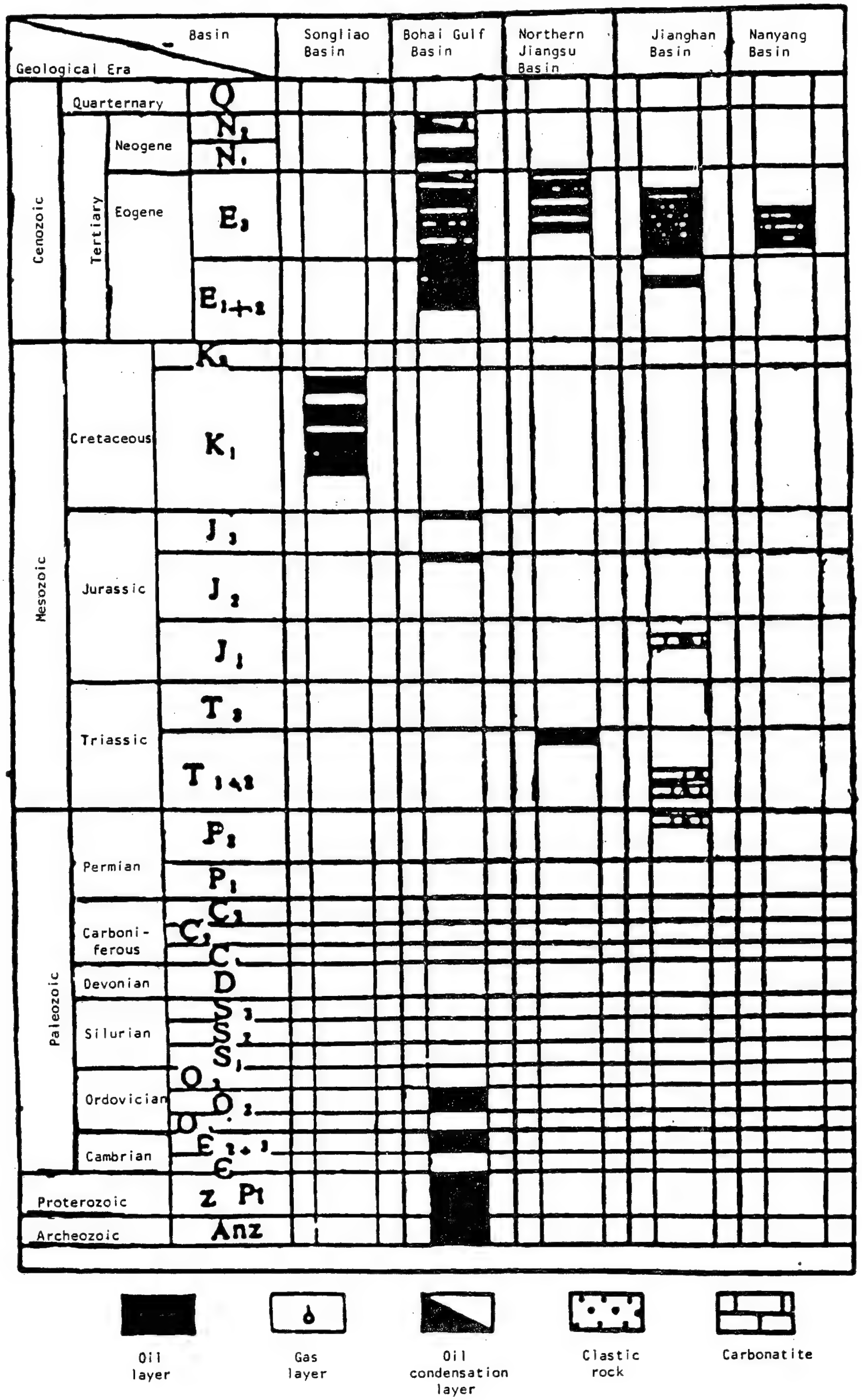
4) Lacustrine turbidite traps. An example is the Gaosheng Oilfield. The reservoir rock is Oligocene sandstone and conglomeratic sandstone.

3. Compound trap oil and gas deposits (mixed structural and stratigraphic factors). There are two known types:

1) Inclined fault-block buried-hill traps. An example is the large Renqiu Oilfield in the Bohai Gulf Basin. The reservoir rocks are Protozeroic siliceous dolomites, Cambrain-Ordovician dolomites and limestone.

2) Paleogeomorphologic buried-hill traps. An example is the Xinglongtai buried-hill oil and gas deposit. The reservoir rock is Archean granite-gneiss and weathered Pre-Tertiary conglomerate.

Figure 6. Longitudinal Profiles of Oil and Gas Accumulation Strata in the East China Continental Oil- and Gas-Bearing Basins



FOOTNOTES

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OIL AND GAS

DEVELOPMENT-GEOLOGICAL CLASSIFICATION OF OIL RESERVOIRS

Beijing SHIYOU KANTAN YU KAIFA [PETROLEUM EXPLORATION AND DEVELOPMENT] in Chinese No 5, 1983, pp 35-38

[Article by Qiu Yinan [5941 0076 2809], Chen Ziqi [7115 5261 3825], Ju Juan [1446 1227], and Tian Zeng [3944 1073], Petroleum Exploration and Development Research Institute: "Discussion of the Development-Geological Classification of Oil Reservoirs in China"]

[Excerpts] Abstract. Reservoir engineers and geologists are much concerned about the classification of oil reservoirs from the development-geological point of view. This paper presents a tentative development-geological classification of the oil reservoirs in China, based on the fact that all of them occur in continental basins. The differences in reservoir rocks and oil properties are the main consideration in this proposed classification, because the characteristics of the lacustrine clastic reservoir rocks not only control the production performance of oil reservoirs directly, they also influence to a great extent other important development-geological features such as oil properties, oil-water relationships, etc. Another main consideration of this classification is that the various development-geological characteristics are regularly associated with one another under a given petroleum geological background. Seven types and twenty sub-types are classified, including the eight sub-types containing most of the oil reserves in China.

Introduction

Geological classification of oil deposits is a question to which petroleum geology workers have always devoted key research and discussion, but the overwhelming majority of existing research has taken trap conditions as the primary starting point. Classification by oil deposit formative factors serves oil field exploration. With oil field development through water injection going to deeper levels daily and the rapid developments in technology to improve recovery rates demands that petroleum geology workers have an even better understanding of oil deposit geology characteristics (especially reservoirs) from the standpoint of oil field development. Much of its content and areas of particular emphasis also differ radically from the demands of oil field prospecting. This is also the reason for the independent

rise of development geology[1] as a separate branch of petroleum geology. Thus, classifying oil deposits from the perspective of development geology characteristics is also part of the agenda of oil field development geology workers. Just as oil deposit classification in the past effectively guided oil field prospecting work, so too, rational classification of oil deposit development geology also plays an appropriate role in improving the effectiveness of oil field development. It can effectively guide exploitation of existing oil fields and improve recovery rates, and also provides experience of the same type oil fields for the rational development and planning of new oil fields.

Geologists and oil deposit engineers have already made a development geology classification of oil deposits. For example, classification according to natural driving methods: dissolved gas driven oil deposits, gas cap driven oil deposits, water pressure driven oil deposits and elastic water driven oil deposits; classification according to the distribution of oil and water: stratified peripheral oil deposits and massive bottom water oil deposits; classification by oil reservoir spaces in reservoirs: porous type, fissure type, and porous-fissure type oil deposits; classification according to quality of crude oil: thick (heavy) oil deposits, thin (light) oil deposits, condensate oil and gas deposits, etc. Actually, these classifications all rely on some important factors which directly influence the development of the oil field, but because they settle on single factors, they cannot comprehensively reflect the characteristics of an oil deposit. To adapt to the development of present oil field development technology, it is necessary to study classification of oil deposits by using the primary geological factors which comprehensively influence development of oil fields.

There are many geological factors which influence development of an oil field. P.A. Dickey[2] feels that continuity, porosity type, inclination, faulting, jointing, geological reserves, gap water saturation, and gas content are important factors. Min Yu]7036 6276] et al.[1] point out that the six important factors are distribution of reserve layers, distribution of pore connecting elements, distribution of fluids, distribution of pores, oil driving capacity, and changes in oil deposits during the extraction process. It should be said that with the development of water injection oil recovery and tertiary oil recovery technology, some factors are still constantly being exposed and understood and for this reason pulling together all development geology factors is an unusually big and complex task as far as carrying out comprehensive systematic and very generally significant classification of oil deposits. By proceeding from the actual geological background of China's oil-bearing basins and from the development-geological characteristics of existing oil fields, this paper attempts to consider the inherent connections between various geological factors and to explore the question of development-geological classification of China's oil deposits. We hope that this work can be of value to exploiting the potential of China's old oil fields and to the development of new oil fields in continental oil and gas bearing basins. As our materials are not systematic or complete, so our understanding of some of the issues covered in this paper is neither precise nor complete, and we hope that our comrades' criticism will correct them and even more that colleagues who are engaged in development-geological work will discuss this question.

I. Basic Development-Geological Characteristics of China's Oil Deposits.

China's existing oil fields which have already been developed were all discovered in such basic oil geological backgrounds as continental oil and gas bearing basins, where oil comes from lacustrine oil producing strata, the reserves are mainly lake basin clastic rock deposits, and fault basins make up a high proportion of the reserves all of which makes up the unique development-geological characteristics of China's oil deposits.

A. Reservoirs

Reservoirs are the heart of oil deposits. The micropore structure, and macro geometrical shape of a reservoir and the compositional type of permeable strata and separating strata of an entire oil reservoir system is the fundamental development-geological characteristic of an oil deposit. It not only directly determines the basic development measures and development results of an oil deposit, but to varying degrees directly or indirectly influences other development-geological characteristics and thus it is a factor which must be taken into consideration first in oil deposit development-geological classification.

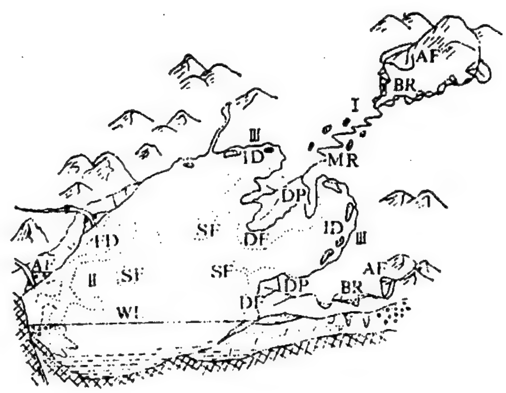

Figure 1 Main types of depositional systems in continental lake basins

I River-delta depositional system
II Alluvial fan-fanshaped delta depositional system
III Interdelta lake bay depositional system
SF Underwater alluvial fan
ID Interdelta lake bay sand
DP Delta plain
AF Alluvial fan
MR Meandering river
DF Delta forward edge
BR Braided river
FD Fanshaped delta
WL Water level

Reservoirs in continental lake basins are undoubtedly primarily clastic rocks, and the primary depositional location of clastic rocks is the depositional system which forms various deltas. Depositional systems which construct deltas can be divided into two extreme types: "river-delta" depositional systems build bird-foot-leaf shaped deltas, and "alluvial fan-fan shaped delta" depositional systems build fan-shaped deltas.[3] These are the two primary depositional systems which make up the overwhelming majority of petroleum reserves in lake basins. In addition, there are two more secondary depositional systems in clastic rock accumulations, viz., lake bay depositional systems between deltas and underwater turbid fan depositional systems (Fig. 1). Clastic rock reservoirs which are created by different depositional systems are essentially very different and this is an important basis for development geology classification of China's lake basin reservoirs.

1. Sandstone reservoirs of "river-deltas" depositional systems

Sand of such environments as alluvial fans, alluvial plains (braided rivers and meandering rivers), delta separation plains, and delta forward edges which rivers with a gradual slope and distant source of materials deposit along their course make up an entire "river-delta" system. Apart from alluvial fans, the deposited material is generally all sandstone reservoirs. Within the same depositional system, from near to far, such structural parameters as granularity, sorting, argillaceous content and regular changes in silt thickness relative to the face of equivalent lithofacies make up the development geology characteristics of this kind of sandstone reservoir.

First, there is a very good interrelationship between its lithic character, physical character, and oil-bearing character.

In sandstone reservoirs of "river-deltas" depositional systems, granularity generally changes from medium sand to grit and silt with fine sandstone predominating, medium sorting, the cement is mostly argillaceous, particle make-up and pore distribution generally presents a danmotai [0830A 2875 1966--monlithic appearance?], porosity varies from 20-30 percent, pore radius mean value varies from several millimeters to several dozen millimeters, permeability ranges from 100 to several thousand millidarcies, and generally has high porosity and medium permeability. Within the same depositional system, granularity basically controls in a regular way the nature of each reservoir, i.e., the greater the mean value of granularity, the greater the porosity, and the greater the mean value of the hole radius, and for this reason permeability and primary oil bearing saturation also increases correspondingly. A linear relationship of rather good interrelationship can be established between lithic character and physical character (Fig. 2). What is even more interesting is that the following phenomenon obtains in micropore structure: the greater the average hole radius, the greater the permeability, and the better the homogeneity of distribution which is closely related to the efficiency of water-driven oil.[4,5] These regular phenomena can be reflected in "river-delta" systems which are built up in a short river in a lake basin, the environmental sandstone structure from near to far is primarily one in which the step changes in granularity are big and other step changes, such as roundness of particles, sorting coefficients, and mineral elements are small, thus very rarely is there clear diversity of diagensis

after deposition, the amount of silt and clayey particles plays an important role in damaging the uniformity of the pores. This regularity of lake basin "river-delta" depositional system sandstone reservoirs is also an important difference with "alluvial fan-fan delta" depositional system psephite reservoirs.

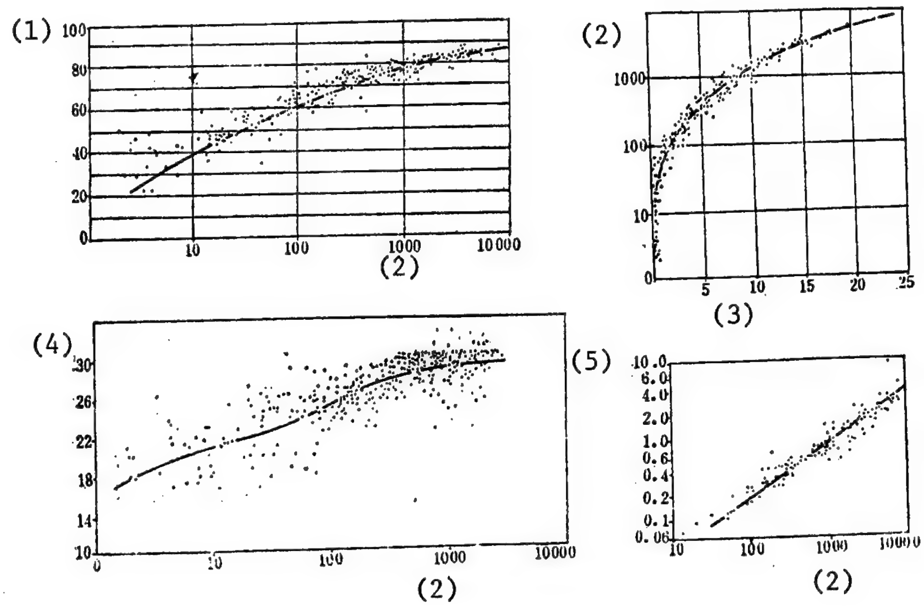

Figure 2. Curve of the relationship between various lithic characters and physical character in river-delta depositional systems (Daqing Oil Field)

1. Oil saturation (%)
2. Permeability (millidarcies)
3. Mean value of pore radius (microns)
4. Porosity (%)
5. Characteristic structural parameters $(\frac{1}{D\emptyset})$

Next, sand is rather fine and generally flows along with the river direction; its lateral continuity is poor.

Since the rivers in "river-delta" depositional systems in lake basins are small, the delta leaf-shaped bodies that they form are correspondingly small and determines that the scale of the sand deposited will also be small. The thickness of a simple sand body can be as small as 1 meter but rarely exceeds 10 meters (in actual work in existing oil fields, sandstone thicker than 4 meters is called a thick layer.) River sand several meters thick itself indicates that the width of the sand body cannot be too great. Many river sand bodies are less than 1 km wide, in particular, some straight sand bodies that divide the river channel are only 100-200 m wide. In some development areas of the Daqing oil field, reducing the 600x500 m well grid to 300x250 m and

300x125 m, increased control of 25-30 percent of the reserves of this type of sand body[6]. Some sand bodies in alluvial plains which are large scale but where the gradient is small, due to the lateral swinging, at various times individual sand bodies may connect laterally to form wider sand bodies, such as the Daqing Oil Field Pu-I[2] layer sandstone which may be 7-9 km wide. However, once water injection is introduced, it was still very clear that the water injected followed the water courses of the individual sand bodies at various times. Since the controlling action of the river clearly exceeds the ability of the lake, sand bars at the estuaries on the forward edges of deltas the direction in which they primarily extend is the same as that of the river flow, thus there are very few sand bodies which are distributed along the shore due to the radical changes introduced by the ability of the lake. Thus, the directionality of the primary body is similarly unusually clear. Of course, thin beds of sand deposited between estuary sand bars dominate river sand bodies and improves lateral continuity.

Third, within sand layers there are two extremes of heterogeneity, i.e., rhythmic channel sand and nonrhythmic estuary sand bars.

A great deal of simulation experimentation and mineral materials reports[8] that rhythmic nature of granularity and permeability are important manifestations of heterogeneity within a stratum. The two types of sand bodies which are the largest accumulations in a "river-delta" depositional system: alluvial channel sand bodies and estuarine sand bars at the forward edge of a delta are two representatives of diametrically opposed non-rhythmic character within a stratum and sand bodies created in other ways are in between these two extremes. Channel-dividing sand bodies basically are rhythmic and the degree of heterogeneity is smaller than in alluvial channel sand bodies. Sand layers which are at the forward edge outside of deltas are thin and very uniform and are basically close to estuarine bars. For this reason, in terms of heterogeneity within a stratum, sandstone reservoirs in "river-delta" systems can also be divided into two sub-types depending on whether they were "above water" or "below water."

Fourth, in many oil strata in which there are multiple cycles in profile, the heterogeneity between strata is complex.

Frequent and large-scale encroachment and retreat of water in a lake basin gives the "river-delta" deposits a clearly multicycle character and in short strata sections, in profile many sand bodies caused by various factors supersede each other and form many greatly divergent oil strata within the stratum (as few as 10 strata or more than 100) is a common sight in such depositional systems and is the main site for forming large oil fields and lake basins.

B. Psephite reservoirs of "Alluvial fan-fan delta" depositional systems

On the short axis steep gradient side of a lake basin, especially the deep fault side of faulting periods, against an ancient geographical background where the steep slope drops and the depositional center is close to an area which is a source of clastic materials, a series of "alluvial fan-fan delta" depositional systems may develop (equivalent to A.D. Miall's[9] second

basin-fill type). Its primary characteristic is that the coarse clastic materials of the alluvial fan directly wedge into the lacustrine mudstone forming a fanshaped delta. With the appropriate trap conditions it can easily form an oil deposit. Coarse clastic deposits primarily of conglomerate and rudaceous sandstone become important reservoirs in lake basins. Their development geological characteristics are very different from the "river-delta" system sandstone reservoirs discussed above.

First, pore structure is unusually complex.

The range of granularity of constituent granules in alluvial fan and fan-shaped delta psephite reservoirs is large, including gravel, sand, and mud, thus the distribution of pores is not only not danmotai but even often more complex than R.H. Clarke's shuangmotai [7175 2875 1966][10]. The large pores in the conglomerate, the small pores in the sand granular structure which fills in the spaces in the gravel, and the micropores of the clay structures which fill in the spaces between the sand grains all can coexist so that pore distribution in this kind of reservoir is extremely uneven, thus its capillary pressure curve generally does not present an "average value section" (Fig. 3). At the same time, it also leads to a lack of any regular relationship at all between lithic character, physical character and oil bearing character. There are great changes in porosity due to varying degrees of many grades of fill, frequently there is an inverse relationship to relative diminution of grade of granules. The permeability of coarse grade rock may be very high because of the existence of many large pores, but at the same time the initial bound water content may be very high as well because of the large number of micropores. Pore separation is extremely poor. The porosity of fine granular rock may be high, but the permeability may be very low. Yet the pore distribution may be very even, and the relative content of the micropores may not necessarily be higher than the former. In practical work, forecasting the relationship between lithic character and physical character in such reservoirs requires careful analysis and differential treatment according to the different rock classification. Pore distribution in which separation is extremely poor may result in lower effectiveness of water-driven oil and is also a major problem in water injection development of this kind of reservoir.

Second, the thickness of a single stratum of sand and gravel rock is rather large and surface continuity is both good and bad.

There are two kinds of continuity of sand and gravel rock reservoirs of alluvial fans and fan deltas. Where clastic bodies provide rather sufficient and stable conditions, coarse sand and gravel rock is deposited on the fan between the main flow axis and flow axes and each fan-leaf formed by depositional events generally is a connected body. Of course, thick, coarse conglomerate deposited within the main flow axis still displays a high porosity zone distributed in a belt shape.[11] This kind of fan generally develops in a rather damp climate and in an ancient environment where the river is the primary machine of transport.

Under the circumstances where the intermittent nature of supply of clastic materials is rather pronounced, the deposition on the fan delta itself is

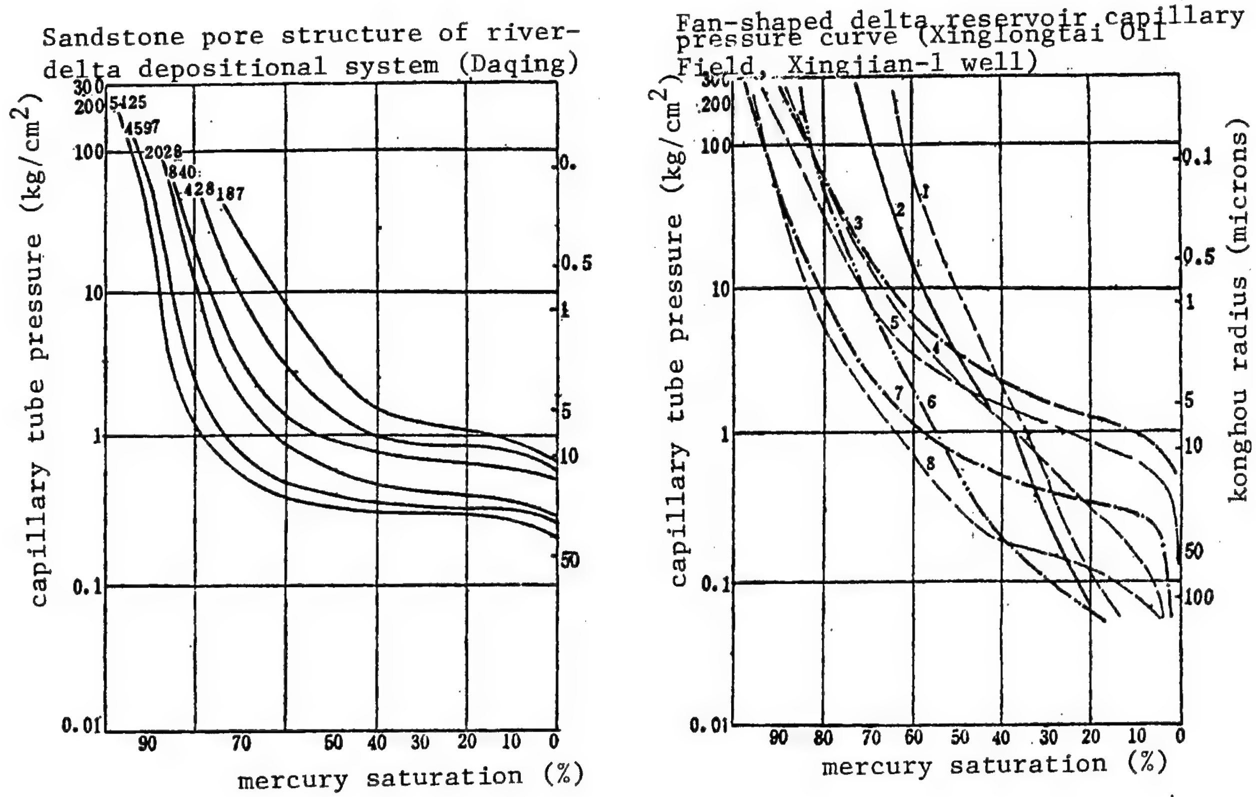

Figure 3. Comparison of the pore structure of sandstone reservoirs of two depositional systems.

(b) Note:	1	2	3	4	5	6	7	8
Ø (%)	24.6	24.7	25.6	23.5	24.3	24.2	26.7	34.0
K (md)	18857	19343	156	422	596	8437	1279	3667

primarily in the form of partition channels and displays a belt-shaped distribution, the bottom of sand and gravel rock bodies and the covering and underlying rock strata both display sudden changes in contact reflecting the violent abruptness of the depositional events, channels are connected by thin sand strata, and at this time the lateral continuity of the sand and gravel rocks is not only poor, but the forward edge portion also frequently rapidly changes to an unpermeable type of rock. Comparatively dry ancient climatic conditions readily created this kind of depositional condition and at this time the alluvial fan portion frequently could be squeezed in between many clastic flow deposits or mud flow deposits and this kind of impermeable mud conglomerate can damage the continuity of the fan in a very complex way.

Third, many heterogeneous classifications with a stratum.

Alluvial fan sand conglomerates mainly are braided river deposits and granularity within a stratum reveals irregular rhythm. Granularity within fan

delta strata can be divided into three situations: generally the lower strata reveal nonrhythm, leading strata reveal compound rhythm, and upper strata reveal rhythm.

However, due to the complex relationship of lithic character and physical character, heterogeneity of permeability does not entirely depend on the granular rhythm. The coarsest conglomerates are not the highest permeable sections, and even if rhythmic granularity making up the section with the highest permeability is not on the bottom, it is beneficial for estimating the water driven thickness wave coefficient.

C. Underwater fan depositional system turbidite

The forward edge of lake basin deltas often develops underwater fanshaped turbidite in deep water environments. To serve as reservoirs it is even more important that the underwater fan's turbid channel portion have a coarse lithic character, and large thickness and bulk. Yet central and extra fan "thin turbidite" portions may not readily become a reservoir of any particular scale because of the fine lithic character of its thinness. All the large underwater fanshaped reservoirs which have been discovered in China so far are of the former type. Short axis gradient underwater fanshaped channels generally deposit very coarse conglomerate. The main lithic and physical traits of such reservoirs are very close to the sand and gravel bodies of "alluvian fan-fan delta" systems. The geometrical form is clearly belt shaped, individual turbidite layer sequence is classicially rhythmic, and the section with the highest permeability is generally in the middle and lower parts. Due to the buildups of many turbid currents in the same channel there may form a thick stratum composed of buildups of many turbidite sequences, reaching several tens of meters in macroform, which is an environment in a lake basin which readily forms thick clastic rock. However, in the development process it is necessary to analyze carefully the thickness of each stratigraphic sequence and the appearance and preservation of "d" and "e" section impermeable rock.

Oil deposits already discovered in sandy turbidite deposited at the forward edge of gentle slope deltas are mostly small scale lens shaped sand bodies completely separated from thick lacustrine argillaceous rock, but core materials are still lacking for detailed structural characteristics.

D. Interdelta lake bay depositional systems.

There are no large scale river supplied clastic materials in the lake bays between lake basin deltas thus the materials must come from proximate delta deposits and some small streams, the lake mainly acts on beach and shallow lacustrine shoal beaches and littoral bar sand bodies. It is characterized by thin strata, distributed in a blanket along the surrounding shore, mineral maturity is high, quartz sandstone can be seen, sorting is good, reservoir pore structure is rather even. Thus, although the capacity of such thin blanket sandstone is not great, productive capability may be very high.

When the supply of clastic materials in lake bays is insufficient, such thin carbonate rocks as biologic limestone and oolitic limestone are normally

deposited and this is an excellent reservoir, most are still porous types, and some develop fissures to become fissure-pore types.

In China's Cenozoic and Mesozoic continental oil and gas bearing basins, many hidden oil deposits have been discovered in ancient landforms, submerged mountains, weathered layers among the early Mesozoic basement rocks. These reservoirs are of the various types of basement rock. Most of the oil deposits discovered now are carbonate rock, a few are metamorphic rock. However, service as a reservoir is always related to such conditions as ancient weathering, ancient rock corrosion, and fissuring, and whether they are pore, fissure, or cavern mediums can be an independent classification consideration in reservoir classification.

B. Crude Oil Quality

The crude oil qualities which have an impact on oil field development are primarily specific gravity, viscosity, wax content, and solidifying point. These things directly involve such important questions as oil well production capability, water injection development norms, oil extraction and collection and transport technology, for this reason it is also an important development geology characteristic of an oil deposit. There are many factors that influence crude oil quality from the parent rock producing the oil: thermal evolution, movement process, preservation conditions, and late period changes all have a big influence on crude oil quality. Crude oil in China's continental oil and gas bearing basin oil deposits generally has the following basic characteristics.

1. The overwhelming majority of crude oil is parafin base crude oil. There is a great deal of plant matter in the oil producing rock in continental basins, water medium conditions in lake basins also run from fresh water to semi-salt water, cellulose and lignin are converted into wax and fatty acids by aerobic bacteria, generally all produce parafin base crude oil. For this reason the high wax content and high solidifying point are basic characteristics of crude oil produced from existing oil deposits in China. In the reservoirs already developed, crude oil with a wax content of over 20 percent makes up over 70 percent of the crude oil, and that with a solidifying point greater than 25° C makes up over 90 percent, of which 15 percent is greater than 30° C.

2. Crude oil viscosity is high. This is a general keynote, and the causative factors are numerous. The Soviet Union's M.M. Ivanova[12] summarizes the water injection development experience of 50 oil fields in such locations as Number Two Baku, and according to the crude oil viscosity divides the oil deposits into three groups, the group with oil strata having crude oil viscosity higher than 5 cp has the poorest development results. Oil deposits in China's existing oil fields in which the crude oil viscosity is greater than 5 cp make up only 11 percent of reserves, i.e., about 90 percent of the oil deposits belong to Ivanova's third group oil deposit classification. From this comparison the clear differences between continental oil sources and marine oil producing can be seen.

3. Changes in crude oil quality of oil deposits within the same oil producing structure generally obey the law of "sichayi juji" [0138 1567 8381 5112 7162]. That is, crude oil located near the bottom of an oil source structure is relatively light and the further up one goes, the heavier it becomes. In general, the deeper in the deposit, the lighter the oil (Table 1).

Table 1. Changes in crude oil quality in the Xinglongtai oil stratum of the Huan-Shuang Oil Field

Block	Surface specific (d^{20}_{4}) gravity	Surface viscosity (cp)	Underground viscosity (cp)
Jin-7 block	0.9870	92.1	/
Huan-17 block	0.0511	718.58	/
Jin-16 block	0.9316	79.7	14.3
Huan-26 block	0.8577	6.38	0.93
Shuang-6 block	0.8434	7.1	<0.5

Due to the uniformity of the sedimentation centers and depositional centers of many of China's lake basins, sand bodies are most developed and the complex interbelting of river and delta deposits most suited to trap large volume reservoirs and structurally most often in a central location and thus within each basin these larger oil fields generally store medium viscosity crude oil.

4. Secondary oil deposit crude oil is characterizied by high viscosity and low solidifying point. Due to the losses of large quantities of parafin and violence of oxidation in shallow places in secondary oil deposits created when primary oil deposits are damaged and the crude oil changes its collection point again, the overwhelming part of crude oil quality is high viscosity (high colloid and asphalt content) and low solidifying (low wax content). Many of the thick oil oil fields which China has already put into production are this type of secondary oil deposit. This kind of regularity also often appears in fault basins, i.e., secondary oil deposits generally move upward from the deep primary oil deposit along the fault and form a reservoir in a shallow deposit, but in lake basins, shallow deposits generally are also products of a period of shrinking of the lake bed and at this time the basins become plains or swamps, without large bodies of water, the river environment occupies the guiding position, therefore this high viscosity, low solidifying oil deposit always has river sand as a reservoir. Next, the shallow reservoir's degree of diagenesis is very shallow, sandstone induration is very poor, thus in development serious heterogeneity of "thick, sandy" and river sand bodies are frequently twinned. The Gudao and Yangsanmu oil fields are examples of this.

5. China also has some thick oil oil deposits which are primary oil deposits in terms of gathering factors, but subsequent actions turned them into thick oil. For example, the Lianhua oil layer in the Gaosheng Oil Field. Contact with a large surface of peripheral and bottom water and oxidation have lowered the crude oil to thick. What conditions promote the powerful oxidation ability of peripheral and bottom water? At present there is insufficient material for

an explanation. However, one phenomenon deserves attention. The primary oil deposit reservoirs in which thickening later occurs are all coarse and thick lithofacies belts. Even some thick oil oil deposits which are formed when later due to structural movements oil layer is exposed on the surface, such as the top part of the Shiyougou Oil Field and Karamay Oil Field 3 and 6 regions, are also similarly coarse and thick lithofacies belts (both are alluvial fan environments). It is very possible that it is still related to the reservoir conditions, and that coarse and thick lithofacies belts favor superseding of hydraulic power and can secure adequate conditions for oxidation or bacterial degradation, and very easily form a relatively high thick oil section.

6. Lake bay blanket sand bodies (and carbonate rock) reservoirs often contain high quality light oil and this is closely interrelated with its environmental conditions. Such reservoirs are rather thin and there are always lithic controlling factors in the formation of the oil deposit. The reservoir is often directly encircled by oil producing rock, after it becomes an oil deposit by drawing on a nearby oil source and without connection with neighboring large deltas or river sand bodies acting as a shield against flexible hydraulic power conditions there are very few opportunities for the crude oil to be degraded through oxidation, and this fostered the fact that lake bay blanket shaped sand is always connected with very light crude oil. Within China, crude oil of such oil deposits is mostly low viscosity oil, such as in the Number IV sandstone group in the mid Shayi of the Xinglongtai Oil Field (6 cp) and the lower Shayi of the Wangxuzhuang Oil Field (1.15 cp). Individual crude oil viscosities are high, but compared with the same structural belt (zone) they are still the lightest.

7. Changes in crude oil quality within the same oil deposit generally obeys the principles of light above, heavy below, and light above, heavy on the sides. This is the consequence of the collection action of peripheral water oxidation and gravitational differentiation of a liquid in the same oil deposit. Secondary oil deposits reveal rather complex phenomena: sometimes there are large differences in crude oil quality in two neighboring reservoirs one above the other within the same oil deposit, but it is still heavy above, light below. For example, the upper and lower oil groups of Guan II in the Yangsanmu Oil Field and the 3-4 oil groups and 5-6 oil groups in the structural top part of the Gudao Oil Field (table 2).

Table 2. Changes in crude oil quality in the Yangsanmu Oil Field

Stratum	Specific Gravity 20°C	Viscosity (cp) 50°C	Solidifying Point (oC)	Wax Content (%)	Colloid + Asphalt (%)
Guan II upper	0.9619	1017.25	-6	5.34	22.74
Guan II lower	0.9496	331.88	-14	5.85	19.75

C. Oil, Gas, and Water Distribution

Analyzing the distribtuion of oil, gas, and water from the perspective of development geology is mainly clarifying the contact relationship of the gas and water regions with the oil region, the ratio of the size of the gas and water in comparison with the size of the oil region, and the connecting conditions of the gas and water and the oil region reservoir. These are directly related to the driving method and the size of the capacity, as well as the ease of energy transfer, and in development are the basis upon which appropriate technological measures are decided.

The depositional characteristics of China's lake basin reservoirs determine to a very large degree the important characteristics of oil deposit oil, gas and water distribution.

1. The overwhelming majority of crude oil is stored in peripheral water bed oil deposits. Basic characteristics of lake basin clastic rock reservoirs (thin, poor lateral continuity, many layered) determine that many can only form peripheral water bed oil deposits. Some primary oil deposits which are reservoirs consisting of river and delta multicycle sand bodies which became large connected sand bodies in the process of forming oil deposits reveal characteristics of massive bottom water oil deposits, i.e., have a uniform oil water interface, such as the Xingshugang and Lamadian oil fields in the northern part of Daqing's Changyuan. This is the product of a prolonged geological history. However in the short history of exploitation, oil and water movement is still in the individual oil sand bodies within the sandstone layer itself and is still a classic bedded oil deposit.

In lake basin clastic rock reservoirs, thick sand bodies (thickness of more than 20 meters) which can form a massive bottom water oil deposit of a certain scale generally have: vertically piled up braided river sand bodies (such as the Guantao group oil layer in the Huanghua Depression), estuary sand bar and fan-shaped delta conglomerates of short axis delta systems and turbid water channel conglomerates in turbid deposit fans (such as the Daling River oil layer in the Liao He depression). However, the general distribution of unstable argillaceous separating layers in these sandy layers makes the characteristics of bottom water driven oil largely inferior (for example, in the center of the Daling River oil layer Jin wells 2-8-11 of the Huanxiling Oil Field, a 54.5 meter turbidite layer has 12 thin separating layers), and with the additional factor that the oil bearing height is not great, from the development perspective, the characteristics of its "bed" must also be considered to a certain degree, and the same development measures for treating a fissure and cavern type carbonate massive bottom water oil deposit cannot be entirely adopted.

A great number of the true bottom water massive oil deposits which have been discovered in lake basin clastic rock reservoirs are "small oil cap" oil deposits formed from a definite structural closure matched with a sand layer of medium thickness, the oil bearing height is very small, generally less than 20 meters (for example, 6-10 meters in the Changqingmafang Oil Field, and 20 meters in the Guantao group oil layer in the region of the Dagang Gangdong Oil Field). They also frequently appear together in an oil

field with a general bed shaped oil deposit which is formed because its single layer thickness is great, or structural position is low, or trap is small and the oil bearing height of the trap is less than the thickness of the oil layer. Extraction practice proves that bottom water zhuijin [6923 6651] is dynamic and because its oil bearing height is small, such measures as perforation control cannot be adopted, for when jointly extracting from other oil strata frequently it becomes an interference stratum in which the water rises very quickly. In water injection development, such "small oil cap" oil deposits must be distinguished very early and appropriate measures for differential treatment be adopted (Figure 4).

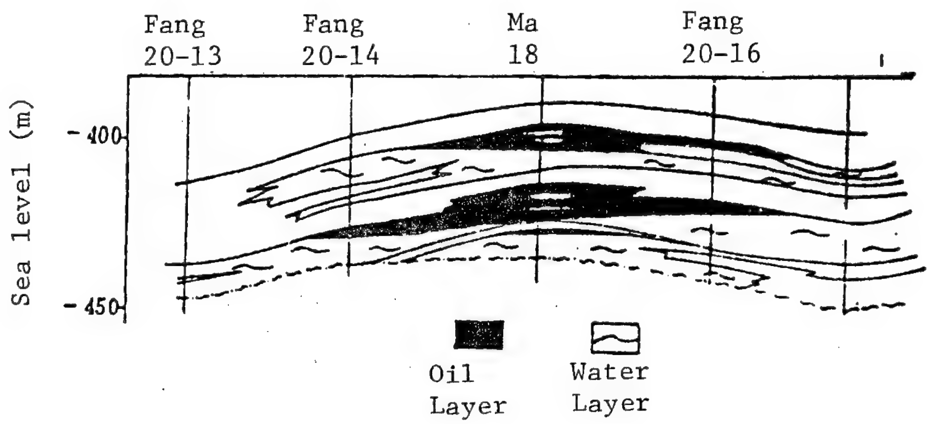

Figure 4. Cross-section of oil deposit in Mafang Oil Field (Yan 10 layer)

2. Peripheral water bed oil deposits may be divided into two basic types. One is that within a certain group or section the separation between oil and water is clear, and one is the complex interspersing of oil and water layers. The former is mostly in multicycle river and delta sand body reservoir primary oil deposits. Connectivity of sand bodies with the same depositional cycle is better than the sand bodies between cycles, and conversely, stability of mudstone between cycles is better than within the cycle. This basic depositional phenomenon makes for very good uniformity between oil and water systems and depositional cycles in the oil deposit formation process. In some oil fields, water and oil are uniformly separated within a large depositional cycle of several hundred meters (as in North 3 Oil Field of Changyuan, Daqing) and in some, within a secondary grade cycle of several tens of meters thickness there is uniform balance (as in the Shengto Oil Field). This close uniformity of oil and water systems and depositional cycles in an oil deposit provides favorable conditions for separately developing layer systems and distributing wells and for developing by layers in oil field development.

The latter type occurs in blanket secondary oil deposits or in fault block oil fields which have been damaged by faults, within one reservoir in an

oil field, water and oil are distributed into individual systems by sand layer forming a complex interspersing of oil and water layers horizontally. The following phenomenon has now been discovered in some interspersed oil and water layers in secondary oil deposits: a sand layer of relatively high permeability and good connectivity, opportunity rate of the water layer is relatively high; yet, sandstone with relatively low permeability and poor connectivity, the opportunity rate of the oil layer is high. For example, the oil deposit in the East 3 section of the Xinglongtai Oil Field (Fig. 5), and the Minghuazhen oil layer of the Gangdong Oil Field. In addition to repeated damage by faulting making it easy for the crude oil in a highly permeable layer to be scoured and lost, it is also possible that when the secondary oil deposits were formed, it was easy for the crude oil to move up from the depths along the fault and enter a sand layers where the hydraulic power conditions were not dynamic. However, whatever the factors, it appears that all achieved similar results, and formation of a blanket secondary oil deposit in a fault basin is a relatively universal phenomenon.

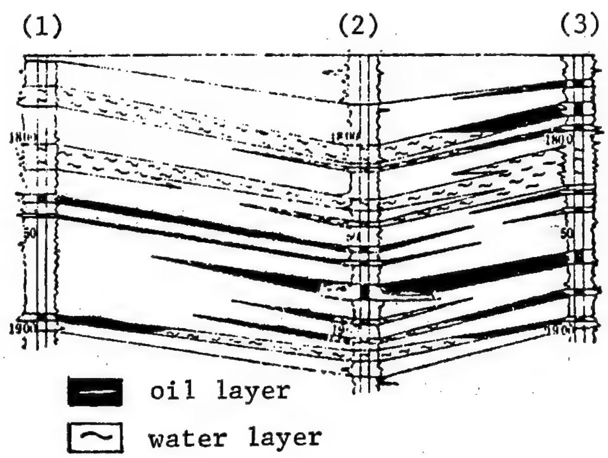

Figure 5. Cross-section of oil deposit in southern part of the Xinglongtai Oil Field (Dongying group, Maquanzi Oil Layer, Second oil group)

1. Ma 511 well
2. Ma 140 well
3. Ma 153 well

3. Basin basement rock oil reservoirs of ancient landforms and submerged mountains are all massive bottom water oil deposits. Weathering, corrosion, and cracking are necessary conditions for the pores and spaces of this type of reservoir and thus stratigraphic water always exists in the form of bottom water and forms massive bottom water oil reservoirs. When these basement rocks themselves are sedimentary rocks which can form layers (such as carbonate rock) or metamorphic rock from sedimentary rock (such as the Dujiatai ancient buried mountain quartzite), due to corrosion and distribution

of cracks, controlled to a certain degree by lithic nature, the degree of development of pores and spaces in each level can be different, during development internally a certain stratum forming character is often evident.

4. Oil deposits which are not driven by large-scale natural water pressure. The basic characteristic of lake basin clastic rock depositional bodies that they are small and scattered not only determines that the majority of oil deposits are bedded peripheral water types, but also similarly determines that there cannot be any oil deposits driven by large scale natural water pressure. Because the prerequisites of good permeable conditions and a reservoir distributed over a large area are lacking, the oil deposits discovered domestically which are driven by natural water or have substantial supplement from peripheral water capacity all are fault blocks or structures which are small in area and marginal development (the largest Yonganzhen Oil Field is 7 sq km, but generally they are smaller than 5 sq km). Even if these small-scale oil deposits become driven by natural water pressure, it still requires a connected water body of several hundred times the bulk of the oil bearing reservoir to act as a shield. In terms of lake basin clastic rock deposits, there must be certain environmental factors, a reservoir of large area or bulk of deposits to make such an oil deposit. From an analysis of this type of oil deposit in existence, most of the reservoirs are of the fan-shaped delta bodies (such as the Yonganzhen Oil Field?), or a thick layer estuary sand bar on the forward edge of a delta formed by a steep gradient, short-run river or a coarse clastic braided river sand body of frequent lateral movement (such as some Guantao group oil strata in the Dagang Oil Field). Of course, never having undergone transformation of violent diagenesis is also an important condition.

The "small oil cap" bottom water oil deposits described above similarly are natural water-driven activity types.

5. The activity of shallow layer secondary oil deposits peripheral water is stronger than deep primary oil deposits. This is speaking relatively. This phenomenon exists in some oil fields in the eastern part of China. As for the activity of the peripheral water of an oil deposit, in addition to determining the continuity of a reservoir, the nature of the peripheral water region's reservoir is also an important condition. In some primary oil deposits in China, it is generally discovered that the physical character of the oil stored in peripheral water regions does not follow the regional type lithofacies tendencies of change but is clearly less than the oil bearing region (for example, the Laojunmiao L oil layer in the northern part of the Daqing Oil Field). This may be due to differences in the water area and the oil area after the formation of the oil deposit as the result of diagenesis, the water area reservoir lost porosity and permeability as it continually underwent intensification of rock forming action. On the other hand, due to the fact that the crude oil above the water and oil interface of many medium viscosity oil oil deposits was oxidized by the peripheral water to a certain degree, there appeared a thick oil section which reduced the invasion of peripheral water. Furthermore, due to the fact that the oil formation period was late in some shallow layer secondary oil deposits, after formation of the oil deposit, the oil area and the water area were not clearly differentiated of the by diagenesis, nor was it sufficient to

form a relatively thick oil section at the water-oil interface. For this reason as long as a reservoir's continuity is good there will be a certain connection between the water bearing area and the oil bearing area and both will more or less exhibit active peripheral water (as in some faults in the Gangdong Oil Field, the Yangerzhuang Oil Field, and the Gudao Oil Field). Making comparisons in the same region other conditions being the same, shallow layer secondary oil deposit peripheral water always is more active than in deep primary oil deposits.

For similar reasons, at the other extreme, some diagenetic trap oil deposits which do not have peripheral or bottom water appear in the depths. For example, in the Xing-20 and Xing-1 wells fault block of the Rehetai oil layer in Sha-3 of the Xinglongtai Oil Field there are oil deposits without peripheral or bottom water. The well produces oil above a depth of 2,150 meters and below that it is a completely dry layer. The 2,150-meter interface may be seen as an oil-water interface at the time the oil formed and in subsequent fossil history, the sandstone of the peripheral water part completely lost its permeability due to the constantly intensifying diagenesis. The natural capacity of the oil deposit is only the elastic capacity and the solution gas drive capacity of the oil bearing area itself. These oil deposits are most related to basin bottom turbidite lenses of large scale lake invasion period of the lake basin. Since research on sandstone reservoir diagenesis is just starting, we must await practical materials to confirm this understanding.

6. There are also two situations in which gas caps function like peripheral water. One is when a unified oil and gas interface existing within a reservoir forms a large gas cap, but the characteristics of the interspersing of bed type sandstone and mudstone in the reservoir and in a similar fashion, in the extraction process the gas cap can permit "processing by layers." For example, the gas caps in the Lamadian, Shuangtaizi, and Banqiao Oil Fields all are primary oil and gas deposits and the gas cap index is large. The other one is when oil bearing sandstone strata have small independent gas caps which are not connected forming a complex situation in which oil and gas are interspersed vertically, such as in the Gudao Oil Field, generally produced in secondary oil deposits and fault block oil fields, where the gas cap index is not large.

In the case of the former, since the gas cap index is large, in developing the oil field it is necessary to treat it conscientiously. This also can be divided into two situations: wet gas gas caps which are rich in light oil, in the process of hydrocarbon movement and collecting first of all collect in lowly positioned structures near the oil source, thus reservoirs of this kind of gas cap oil deposit are mostly delta forward edge and remote shore sand bodies, such as the Banqiao and Shuangtaize Oil Fields. The other is the dry gas gas cap. Such gas cap reservoirs are mostly ones which changed from primitive unsaturated gas cap oil deposits and gas cap oil deposits which underwent subsequent structural changes into supersaturated ones, the gas composition of the gas cap is over 90 percent methane, such as the Lamadian Oil Field. Reservoirs with different regional structural position and different belts may appear, thus there is no regularity of reservoir fit.

There is another not very important gas layer production state in oil deposits, i.e., lens-shaped sandwich gas unconnected with the oil layer. Independently sandwiched in between the oil layers, which may appear in any position in a cross-section or plane, these reservoirs are of low permeability silt or fine sandstone. It is because of its low permeability that in the long process of differential balancing of oil, gas and water within an oil deposit, it is hard for the crude oil to be further transposed and it is left in the lower gas sand sandwich layers, in the early period of recovery it frequently interferes with oil well production, but once it is released, things return to normal. For example, such sandwich gas layers have appeared in the same areas in the northern and southern parts of the Daqing Oil Field.

D. Fissures

Fissures are an important seepage channel and they also have a certain capacity to store oil. Fissures are an indispensible condition in basement rock oil deposit reservoirs in China's continental oil and gas bearing basins. And the development of fissures in clastic rock reservoirs to make them fissure-pore type reservoirs is generally related to their densely cementing lithic character and the low permeability. The fissure-pore type reservoirs of this type already discovered in China have the following characteristics.

1. The reservoirs are largely layers of low permeability formed through diagenesis, have secondary quartz enlargement to varying degrees, and deep cementation. For example, the Fuyu oil layer in the Fuyu Oil Field, the M oil layer in the Laojunmiao Oil Field, and the Yanchang group oil layer in the Majiatan Oil Field. Three clastic rocks with low permeability can be seen in lake basins: 1) Fine clastic rock with high argillaceous content from far shore deposits; 2) Coarse clastic depositional material with poor sorting (often seen in alluvial fan environments); 3) Dense sandstone after diagenetic transformation, granularity is not very fine but it has lost a great many of its primary pores due to diagenetic cementation and secondary pores did not develop. Fissures do not develop in the first two kinds, but fissure-pore type sandstone reservoirs are seen only among the latter which demonstrates that the degree of cementation density of sandstone--the size of its plasticability--is an important internal cause for the development of fissures.

2. Distribution of fissures is controlled by partial structure and is not characterized by direct control of clearly regional structural stress. For this reason, the distribution of fissures in an oil field is very uneven and they develop in places where the partial structures curve is high. For example, in the Laojunmiao M oil layer tension fractures develop primarily along the a fault belt parallel to the axial and flank portion s of the structural axis; structural cracks in the Fuyu oil layer in the Fuyu Cil Field are primarily in vicinity of the fault and structural flank where the angle of stratum tilt becomes sharp.

3. The natural productive capacity of many fissure systems is not clear when put into production but after water injection they immediately become evident. This indicates that the degree of fissure development is not high

and that latent fissures are numerous, core observations do not cut through mudstone sandwich layers, there is no clear connection between the layers, but when water is injected layer separation can be controlled. After the water injection line has been adjusted along the distribution of fissures, the results of water injection clearly improve.

II. Views on Development Geology Classification of China's Oil Deposits

The aim of a development geological classification of oil deposits is to set out the clear development geological traits of various kinds of oil deposits to benefit the research on suitable extraction measures; summarizing the basic laws of extraction dynamics of different kinds of old oil deposits also benefits the developmental design and evaluation of new oil deposits. The geological face of an oil deposit is the sum of its various features, but even if a mechanical classification combination is carried out according to the above-described four main aspects, over 100 types can be derived which leads to trivial results. In fact, an oil deposit which is formed against a certain geological background, the geological phenomena cannot be simply combined mechanically. There are certain inherent connections between them and if these connections are stressed, and the important contradictions which affect development are brought out, it will be possible to derive an oil deposit classification in which the traits are clear and not trivially complex. The views we present here with regard to the development geological classification of China's oil deposits is based on a search of this kind of knowledge, at present we have not yet added in the limits of strict oil deposit engineering and for this reason it is still only a natural combination of geological characteristics.

The main points of departure in considering this classification are:

First, reservoir traits were made the first basis of classification. From the basic development geology characteristics of China's oil deposits described above, it is not hard to see that the special clastic rock depositional characteristics of lake basins not only determine the face of the reservoir and reservoirs of completely different heterogeneity formed by different depositional systems, but also the developmental geology characteristics which influence it directly or indirectly. For example, the bed marginal water oil reservoirs occupy a dominant position; uniformity of oil and water systems and depositional cycles in primary oil deposits; closeness of the relationship between thick oil oil deposits and coarse, thick lithofacies belts; secondary oxidized thick oil oil deposits also are often loose granular river sand bodies; condensate gas cap oil deposits are mostly discovered in sand bodies on the forward edge of deltas; lake bay sheet sand generally stores light oil; large-scale compound river-delta reservoirs generally contain medium viscosity oil, etc. Basing it on lake basin depositional systems in this way first of all permits dividing clastic rock reservoirs into three types: I, river-delta depositional system sandstone reservoirs. When conditions permit, for example, when researching oil deposits according to developmental stratigraphic series or regional blocks, two categories can be specifically distinguished: river and bodies (on land) or delta leading edge sandbodies (underwater); II, conglomerate

reservoirs from alluvial fan-fanshaped delta-turbidite fan shaped depositional systems; and III, blanket sandstone reservoirs of lake bay depositional systems between deltas (including associated thin carbonate rock).

After sandstone has been through deep diagenetic transformation, fundamental changes take place in the nature of the reservoir, a large number of the primary pores are lost, secondary pores may become the main space for storing oil, and fissures may also develop even more with lithic density. Although research on sandstone diagenesis is just getting under way in China today, and it is still impossible to discuss its development geology traits, from work at Maling Oil Field[13] it can already be seen that this type of reservoir will confirm its special laws, for example in the Yan 10 layer oil layer in Maling Oil Field, the pore uniformity diminishes as the permeability increases, and its tendencies happen to be the reverse of the river-delta sandstone reservoirs which have not been gone through violent diagenetic transformation. For this reason it is listed as reservoir classification IV, and becomes a separate type.

Carbonate rock reservoirs of ancient submerged mountains, undoubtedly should be ranked independently as type V reservoirs. Since their storage capacity is rather small, they are not further subdivided. Other basement rock reservoirs which also store oil in fissures or caverns have small storage capacity at present, and are not separated classified but are classed with carbonate rock basement rock reservoirs.

Second, crude oil quality is taken into account. When crude oil quality is unusually special, it can become a factor which must be considered first when extracting it, and the reservoir and other geological factors are demoted to secondary position. There are two situations here: one is when crude oil is of the thick oil type, at which time water injection is not effective or when hot extraction must be used. The second is when there is a large and rich gas cap in the oil deposit, and preventing loss of condensate oil during extracting becomes an important key. For this reason, it is necessary to make these two situations the basis for one type and rank it with the five types listed above, making thick oil oil deposits type VI, and rich gas gas cap oil deposits type VII. The oil deposit engineering limitations of thick oil domestically has always been an oil layer viscosity greater than 20 cp. In the view of Comrade Liu Wenzhang (restricted report) an oil layer with specific gravity greater than 0.934, and viscosity greater than 50 cp is heavy oil and must be heat extracted. Following customary practice, this article considers oil above 20 cp to be thick oil and must be heat extracted. Following customary practice, this article considers oil above 20 cp to be thick oil, and within thick oil, and further subdivides at 50 cp.

Finally, the above seven types are further subdivided according to other geological factors of oil deposits, taking natural combinations into account. Since crude oil quality has a big influence on development, apart from thick oil, there are the two subtypes of medium viscosity oil (5-20 cp) and low viscosity oil (<5 cp). Oil, gas and water distribution highlighting bedded peripheral water, massive bottom water, and with dry gas gas caps are divided into three subtypes. As concerns the naturally driven oil deposits,

in modern development, when there is insufficient natural water for driving, generally water injection development is used as much as possible. For this reason, whether or not there is active peripheral water is a key point which should be considered in classification. However, as was said above, large-scale natural water-pressure-drive oil deposits do not readily appear in continental oil and gas bearing basins, therefore, in this type there is no one factor for subtyping. When determining subtypes in practice, very few combinations appear which do not fit the type. For example, river-delta sandstone reservoirs do not take into account the massive bottom water subtype; basement rock oil deposits do not take into consideration the bedded peripheral water subtype.

Conclusion

1. The special depositional environment of continental lake basins determined the type and nature of reservoir, and the reservoir further directly or indirectly influences its important development geology traits. This article has used the different reservoirs and the special nature of liquids as the basis for a development geology classification of oil deposits, and has divided China's oil deposits into 7 major types and 20 subtypes, of which 8 subtypes are the most common.

2. This classification is based on the associations of contributing factors in development geological traits, and must be further combined with oil deposit engineering research, to put forth strict oil deposit engineering boundaries.

This paper also drew on materials from unpublished, restricted reports by comrades Jiang Shaojin [5592 4801 6855], Zhang Rui [1728 6904], Zhang Suhua [1728 4790 5478], and Song Shaoying [1345 1421 5391], to whom we offer special thanks.

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8226
CSO: 4013/73

BRIEFS

SHANDONG 1ST QUARTER OUTPUT--As of 31 March, Shengli oilfield has produced 5.01 million tons of crude oil, an increase of 680,000 tons over the corresponding 1983 period, overfulfilling the state plan by 2.3 percent. This oilfield has produced 280 million cubic meters of natural gas, surpassing the state plan by 3.8 percent. [Excerpts] [Jinan Shandong Provincial Service in Mandarin 2300 GMT 31 Mar 84 SK]

CSO: 4013/150

DISPOSAL OF SPENT REACTOR FUEL SAID TO POSE NO INSURMOUNTABLE PROBLEMS

HK010940 Beijing RENMIN RIBAO in Chinese 18 Apr 84 p 3

[Article by Jiang Shengjie [1203 5110 7132], chairman, Science and Technology Committee, Ministry of Nuclear Industry, and Huang Qitao [7806 7871 7118], chief engineer, China Atomic Energy Industrial Company: "A Talk on the Processing of Spent Fuels From Nuclear Power Plants"]

[Text] Nuclear power is an energy resource with very good prospects. By the end of 1983, in 24 countries and regions in the world, a total of 302 nuclear power plants were operating, with a total installed capacity of 200,000 megawatts. It is predicted that by 1990, there will be 537 nuclear power plants with a total installed capacity of 420,000 megawatts. China also has started building nuclear power plants. By the end of this century, a number of pressurized-water reactor nuclear power plants will begin operation and will make due contributions to the attainment of our country's strategic goals.

Pressurized-water reactor nuclear power plants use low concentration uranium containing about 3.2 percent uranium 235 as their fuel. A 1,000-megawatt pressurized-water reactor nuclear power plant needs to be loaded with 80 tons of uranium as its fuel, and one-third of its fuel, or about 27 tons, has to be replaced annually. The spent fuel removed from the reactor is still strongly radioactive. Therefore, the proper treatment of spent fuel is a matter of great public concern in countries all over the world. Some people doubt that spent fuel treatment techniques have been mastered; some people worry that the after-use treatment process causes environmental pollution, and so on. These worries are understandable but unnecessary.

People often describe the used nuclear fuels from nuclear power plant as "nuclear waste" or "radioactive refuse." These terms mislead people to think that they are purely waste materials which are not only useless but can cause grave, harmful effects because of their radioactivity. Actually, this is not true.

Nuclear power plants use fuel in a way different from thermal power plants; the latter can burn away all the fuel such as coal or petroleum, but the former cannot "burn" away all the nuclear fuel. The spent fuel from a pressurized-water reactor still contains a large quantity of uranium.

Moreover, plutonium, a new nuclear fuel, is produced in the spent fuel. This kind of plutonium differs from another kind of plutonium used for making nuclear weapons and it can be used for industrial purposes. Aside from plutonium, there are considerable quantities of superuranium elements, such as neptunium, americium, curium, and so on, which do not exist in nature, which are artificially synthesized elements, and which are very valuable. To sum up, quantitatively speaking, useful substances constitute a majority of the used fuel from nuclear power plants. However, to utilize these useful substances, we must process them, and this process is known as spent fuel treatment in nuclear industrial production. Spent fuel treatment is an indispensable and important link in the entire nuclear fuel cycle. There is no question about its importance.

Spent fuel treatment has the following advantages:

1. With the retrieval of uranium which has not been "burned" away, uranium resources can be more fully and rationally used. From a 10,000-megawatt pressurized-water reactor nuclear power plant, 250 to 300 tons of spent fuel is removed annually which contain 238 to 286 tons of uranium that has not yet been "burned" away. The recovery of uranium for our use through after-use treatment means that we can annually reduce the excavation and processing of natural uranium ore by 200,000 to 300,000 tons. This is very important to our country.

2. Large quantities of plutonium for industrial use can be made available. From the fuel removed from a 10,000-megawatt pressurized-water reactor nuclear power plant, around 2.3 to 2.7 tons of plutonium can be obtained annually. This kind of plutonium can be used as a fuel for fast neutron breeder reactor nuclear power plants, or can be mixed with natural uranium to form oxide fuels for replacing low concentration uranium fuel used in regular pressurized-water reactor nuclear power plants.

3. Superuranium elements such as neptunium, americium, curium, and so on, can be extracted and then used by various national economic sectors. Neptunium 237 can be used as a raw material for producing plutonium 238, which can be used to manufacture nuclear cells for use in the astronautic sector. Americium 241 can be used in the processing of neutron sources, smoke alarms, static electricity removers, and so on. At present, there is a world-wide shortage of these products.

4. Nonradioactive rare gases such as xenon and valuable metals such as palladium and rhodium can be isolated and recovered to make up for the inadequacy of natural resources. Radioactive cesium 137 can be isolated and recovered and used as a source of radiation in food storage, industrial sterilization, and so on.

5. Because radioactive elements with a long half-life, such as plutonium, neptunium, and so on, are removed, the radioactivity of the waste substances from used nuclear fuels is greatly reduced, so that the technical difficulty in the safe storage of these waste substances is greatly reduced.

Today, several countries have already mastered the techniques of treatment of spent fuel components from pressurized-water reactor nuclear power plants. China mastered military-purpose spent fuel treatment techniques long ago, and has carried out a great deal of scientific research concerning this treatment of fuels from pressurized-water reactors. If we further vigorously grasp technological development and organize the forces from various quarters to cooperate, it is absolutely possible for us to master quickly the entire technology in this area.

The treatment spent fuel from pressurized-water reactors can be roughly divided into four aspects: The transportation of components, intermediate storage, treatment, and the final disposal of strongly radioactive waste. No one doubts the safety of the first three aspects because of the many years of world-wide experience. For example, many countries have had large quantities of nuclear fuels transported over land and sea and no accident has ever occurred. Over the past 20 years or more, a great deal of experience has been accumulated in using water tanks for the intermediate storage of spent fuel from pressurized-water reactors, and this has proved to be safe and reliable. New techniques of intermediate storage are being developed. Spent fuel treatment can be carried out without any conspicuously undesirable effects on the environment if the plant site is appropriately chosen, if relatively high safety and precautionary standards are adhered to, if rigorous safety and precautionary measures are adopted, and if management and operation standards are raised. The records of many spent fuel treatment plants at home and abroad have proved this point.

The final disposal of strongly radioactive waste means the adoption of appropriate methods to permanently isolate this kind of waste from man and all other living organisms. Over many years, various countries have put forth many disposal schemes, for example, burying the waste deep in the earth's strata, in the deep seabed, in the arctic ice, or sending it into space. Judging from present circumstances, a relatively practical method is to bury it deep in the earth's strata. The safety of this method has been acknowledged by more and more people. In October 1980, the United States Department of Energy published the "Report on the Environmental Effects of the Final Disposal of Commerical Nuclear Waste in the United States," which formally put forth the scheme of digging nuclear waste storage spaces deep in the earth's strata, and which expressed the resolution to build the first national storage space to be completed and to go into use by 1998. This resolution demonstrates that the final disposal of strongly radioactive waste has now gone beyond the stage of study and initial development, and has entered the stage of full-scale industrial application.

Some people have made the following estimation: If an underground storage space of this category is built within 70 km of a district with a population of 2 million, the dosage of radiation which is collectivley received by the residents during excavation and which is caused by radon and its derivatives will be 1 percent of the basic natural figure, while the dosage received by the residents in the case of an accident caused by the damage of a container in transit holding some nuclear waste that has been cooled

for 20 years will be 0.1 percent of the basic natural figure. In analyzing the risks associated with storage spaces, some foreign countries have also made estimations about the consequences of various kinds of major accidents, for example, the impact of a huge meteorite right above a storage space, flooding caused by the rupture of rock layers, the infiltration of underground water, and so on. Even if these things occur, the dosage of the resulting radiation will be merely around 1 percent of the basic natural figure.

It should be mentioned that some 2 billion years ago a natural large-scale chain reaction fission of uranium occurred underground below (Ao-ke-luo) in Gabon, Africa. Today, this "natural reactor" has been continuously working for 600,000 years. The majority of residue from nuclear fission and the majority of superuranium elements remain in the neighborhood of the place. This discovery strongly proves that a favorable geological environment can ensure that radioactive nuclear substances can be permanently separated from the biosphere. Actually, the radioactivity of nuclear waste stably stored underground is neglible compared with that of the "natural reactor." The disposal of nuclear waste deep in the earth's strata is safe and relible.

China has a vast territory. There are many sparsely populated areas with stable geological conditions. Compared with certain densely populated countries with a small territory, we are in a favorable position for developing the disposal of nuclear waste deep in the earth's strata.

CSO: 4013/160

INTENSIVE GEOLOGICAL WORK PRECEDES NUCLEAR POWER PLANT SITE SELECTION

Hangzhou ZHEJIANG RIBAO in Chinese 16 Apr 84 p 1

[Text] In early April, preliminary geological survey work began on the Huadong Nuclear Power Plant, the second such plant the State plans to build in Zhejiang Province.

The design power of this nucelar power plant will be twice that of the Qinshan facility. After this major national construction project is finished, even more energy will be made available for the development of the Shanghai Economic Zone. The overall geological and engineering geological surveys are being handled by the Provincial Geological Minerals Bureau. This bureau drew up detailed geological work plans and quickly assembled personnel from eight geological and specialized brigades (representing hydrography, engineering geology, geophysical surveying, cartography, and regional geological surveying, etc.) to form a specialized grass-roots unit. A senior engineer was appointed as the unit's chief engineer. He was provided with 25 engineers and assistant engineers. The bureau's leadership also went to the work site to make on-the-spot studies and arrangements. In order to accelerate progress, geological personnel who had just gone to the unit braved rain to carry out all kinds of field survey work, including geophysical exploration, cartographic work, and hydrological and geological surveys. Initial progress has now been realized. The aerial geophysical and magnetic survey teams of the Provincial Geological Minerals Bureau will soon undertake aerial magnetic survey missions.

CSO: 4008/295

NUCLEAR POWER

EXPERTS SEEK TO EASE FEARS OF ENVIRONMENTAL CONTAMINATION

OW200325 Beijing XINHUA Domestic Service in Chinese 1252 GMT 18 Apr 84

[Excerpts] Beijing, 18 Apr (XINHUA)--Two nuclear experts from our country pointed out today: Although the radioactivity of spent nuclear fuel is still very strong, it is possible to prevent environmental pollution from such radioactivity, if reprocessing technology is properly applied.

With the development of nuclear power stations, some people at home and abroad worry about nuclear contamination. One of the problems which concerns people is that the strong radioactivity of fuel used by nuclear power plants may cause environmental pollution. On this problem, Jiang Shengjie, chairman of the Scientific and Technological Committee under the Ministry of Nuclear Industry, and Huang Qitao, chief engineer of the China Atomic Energy Industrial Company, jointly wrote an article entitled "On Reprocessing Fuel Used by Nuclear Power Plants." The article says that it is understandable that people have such misgivings, but it is unnecessary for them to worry.

The article says: People commonly refer to the nuclear fuel used by nuclear power plants as "nuclear waste" or "radioactive refuse," and describe it not only as useless but as very harmful because of its strong radioactivity. Actually, this is not the case. The way a nuclear power plant uses its fuel is different from how a thermal power plant does--the latter can consume such fuels as coal or oil, while the former cannot "burn" nuclear fuel completely. Spent nuclear fuel still contains a certain amount of uranium; in addition, it also produces a new nuclear fuel, plutonium, and such transuranic elements as neptunium, americium and curium. These transuranic elements, which do not exist in nature, are very valuable synthetic elements. In a word, most of the fuel used by a nuclear power station is useful material.

The article says: Several countries have now grasped the technology to reprocess nuclear fuel, and our country has also done a lot of scientific research on such technology. It is entirely possible for us to grasp all the technology necessary to reprocess nuclear power plant fuel rapidly, provided we organize forces in various quarters to make coordinated, vigorous efforts to further develop the necessary technology.

The article admits: Reprocessed nuclear fuel is still radioactive, which may cause environmental pollution. Using proper methods to cope with this problem, such as burying reprocessed nuclear fuel deep underground, it will be isolated forever from humans and other living organisms.

CSO: 4013/149

DESIGN FEATURES OF 300 MW PWR POWER STATIONS DESCRIBED

Chongqing HEDONGLI GONGCHENG in Chinese Vol 4 No 4, 1983, pp 1-6

[Article by Pan Xiren [3382 4762 0086] and Zhao Jiarui [6392 0857 3843]: "The Main Design Features of 300 MW PWR Power Stations"]

[Excerpts] In this article we briefly discuss the main design features of existing 300 MW pressurized-water reactor power plants in foreign countries and the Qinshan power plant China started to build and compare their performance parameters.

II. Design Features of the Reactor

1. Features of the nuclear design

(1) In order to improve the reactor performance and lower the cost of power production, all the most economic reactors today use the method of zoned fueling according to concentration and zoned refueling in the operating life of the reactor. This method not only reduces the nonuniformity of the nuclear power but also increases the burning depth of the fuel assembly. The average rate of fuel consumption of today's foreign nuclear power plants is 30,000 MWd/tU and maximum consumption may reach 50,000 MWd/tU.

(2) Another important practice for improved fuel utilization is to achieve control by a combination of boric acid solution and control rod assembly. This also facilitates an even power distribution and a simplication of the reactor structure. Today, almost all pressurized-water reactors have adopted this practice.

(3) Most power station reactors have a reactor core neutron flux monitoring system, which monitors the axial and radial neutron flux distribution in the reactor core in the power range of 15-100 percent and thereby monitors the power distribution and nuclear nonuniformity coefficient in the reactor core, insuring a safety margin for the operation. It allows adequate time for the reactor operators to take corrective measures when the reactor core shows power asymmetry, anomaly, and drooping. It also accumulates fuel consumption data for optimum refueling. The use of a neutron flux monitor also greatly improves the safety and the economy of the nuclear power plant.

Table 1. Comparison of Features and Parameters of 300 MW (electric) Power Plants

			Chooz	Obrigheim	Ginna	Bezneou-1	Mihama-1	Qinshan
Station name			Chooz	Obrigheim	Ginna	Bezneou-1	Mihama-1	Qinshan
Country			France	West Germany	United States	Switzerland	Japan	China
Thermal power (in 10 MW)			90.5	105.0	152.0	113.0	103.1	103.5/96.6
Reactor core		O.D./thickness of cladding, mm	9.8/0.38	10.75/0.752	10.72/0.61	10.72/0.65	10.72/0.65	10/0.7
Reactor core	Nuclear fuel	Cladding material	stainless steel	Zirconium-4 alloy				
Reactor core	Nuclear fuel	Fuel rod layout	15x15, 20	14x16, 16				15x15, 20
Reactor core	Nuclear fuel	Active length, m	2.68	2.75		3.048		2.9
Reactor core	Nuclear fuel	Pressure, ata		27 ± 1	20-30			20
Reactor core	Frame	Frame material	stainless steel	Inconel-718				GH-169
Reactor core	Frame	Number of layers	9	7	8	7	8	8
Reactor core	Fuel assembly	Type of fuel assembly	Boxed	No box				
Reactor core	Fuel assembly	Type of control rod	Crossed	Bundled				
Main pump		Type	Shielded pump	Upright, single-stage, sealed axle accentric pump (bottom inlet, horizontal outlet)				
Main pump			Model	K.S.B.	Model 93D 6000 HP	Model 93A 6000 HP	Model 93A 6000 HP	
Main pump		Design head, m	53	69	77		61	75
Main pump		Flow rate, m^3/h	6020	1450	20400		15900	16100

[continued]

Table 1. [continued]

	Type	Upright U-type	GHH	Model 33			Upright U-type
Evaporator	Heat transfer tubes	Stainless steel	Inconel-600				Incoloy-800
	Heat transfer area per unit, m^2	1385	2750	2508.3		2063.7	3060
Turbine	Design capacity, kw	282000	320000	496322	2x182000	340000	300000
	Calculated capacity, kw	325000	340000	516739			322000
	Revolution, rpm	3000	3000	1800	3000	1800	1500
Fueling/ Refueling	Shutdown, days	25	21	50	20	21	30
	Refuel time, days	12	11.3	12	12	12	12
	Annual refuel, ton/year	12	11.3	12	13	13	13.47
Construction period, years		1961-67	1964-69	1965-70	1965-70	1966-70	1982-88

The nuclear design of the Qinshan power plant followed the criteria and practices widely adopted by foreign power plants.

Table 2 shows a comparison of the design parameters of Qinshan power plant and foreign power plants of the same type. As can be seen, the reactor specific power designed for Qinshan is almost equivalent to that of similar foreign plants and the nuclear nonuniformity coefficient is even lower than its foreign counterparts.

2. The criteria and features of heat engineering design

The general criterion for the heat engineering and hydraulic design of a pressurized-water reactor is that under normal operation no components will be burned out. In the design of foreign reactors this criterion is achieved by requiring the minimum burnout ratio computed from the W-3 critical heat flow density equation to be greater than 1.3. In addition, the heat engineering and hydraulic design will not permit melting at the center of the fuel core. That is, the temperature at the center of the fuel should always be lower than the melting point throughout the lifetime of the fuel.

The main goal a reactor heat engineering design should strive for is a high average power density and a low flow rate. The former allows a greater power output for an equal load of fuel and the latter allows a minimum power consumption of the pump.

The heat engineering design of the reactor is closely related to the nuclear design of the reactor core and the structure of the grids. The main task of the heat engineering and hydraulic design is the proper choice of the operating pressure, the coolant temperatures at the inlet and outlet and the coolant flow rate for optimum technical and economic performance while satisfying the criteria of heat engineering design and taking both nuclear design and structural design into consideration.

Table 3 shows the heat engineering parameters of Qinshan determined after evaluating the various plans. As can be seen, the heat engineering parameters of the Qinshan power plant are roughly comparable to those of foreign 300 MW PMR reactors. The maximum line power density is somewhat lower, which makes the operation even safer.

3. Features of the mechanical design

The reactor consists of the reactor core, the interior structure, the pressure vessel and the control rod drive mechanism. In view of the fact that the reactor contains radioactive material, there is strong neutron and γ radiation during operation and the components must operate for long periods of time under high temperatures, high pressures, strong radiation, and the corrosion of water containing boric acid, the reactor must satisfy the following criteria in structural design: All components must have sufficient strength and hardness at the operating temperature, the total deformation of the vessel must be less than 1 percent and it must withstand thermal expansion and water impact while maintaining the structural integrity. The

Table 2. Comparison of Nuclear Design Parameters

Power station name	Chooz	Obrigheim	Ginna	Bezneou-1	Mihama-1	Qinshan
Weight of nuclear fuel, tons	45	35.2	53.3	45.3	40	40.32
Reactor core diameter, m	2.50	2.50	3.45	2.45	2.45	2.486
Reactor core height, m	2.68	2.750	3.660	3.050	3.050	2.900
Concentration, percent ^{235}U	2.93/3.25/3.75	2.5/2.8/3.1	2.44/2.78/3.48	2.4/2.8/3.0	2.27/3.03/3.4	2.4/2.67/3.0
Average consumption, MWd/tU	26000	24000	21800	27000	31500	24570
Control method	cross rod +chemical	bundle rod +chemical	bundle rod +chemical +solid	bundle rod +chemical	bundle rod +chemical +solid	budle rod +chemical +solid
Total number of control rods (long/short)	30	32	29/4	25/4	29/4	37
Grid distance, mm	13	14.3	14.1	14.1	14.1	13.3
Maximum excess reactivity k_{eff}		1.2800	1.2750	1.2700	1.2750	1.2690
Specific power, kw/kg	22.79	30.88	24.38	24.94	25.75	25.40
F_g	3.25	3.1	3.28	3.25	3.14	2.90
$F_{\Delta H}$	1.95	1.9	1.75	1.88	1.75	1.67

Table 3. Comparison of Heat Engineering Parameters

Power station name	Chooz	Obrigheim	Ginna	Bezneou-1	Mihama-1	Qinshan
Electric power (gross/net) in 10 MW	32/28.2	34.5/32.8	49.8/47	36.4/35	34/32	32.2/30
Efficiency	29.3	31.15	32.0	32	32	31.1/31.05
Average power density, kw/1	69	76.8	89	78	71	73.5/68.6
Working pressure, ata	141	145	157	157	157	155
Inlet temperature. °C	265	283	289	284	289	287.9/288.8
Outlet temperature, °C	302	312	316	314	317	316.1/315.2
Steam pressure, ata	36	55	51.3	57	55	53.5
Steam temperature, °C	245	264	264	272	270	276.9
Steady state minimum burnout ratio	2.11		2.15	1.94		1.94
Fuel center temperature, °C		1820	2138	2120	2234	2024
Maximum linear power density, kw/m	41.9		54.1	54.3	49.2	43.6

material should be resistant to corrosion and radiation. As there are also stringent requirements on the oxygen, hydrogen, and chloride contents, pH value, and residue in the coolant, the material corrosion rate must be less than 10 mg/dm^2 per month. The heat engineering design also sets requirements on the incident conditions. Under the extreme case of simultaneous occurrence of earthquake and main pipe rupture, the reactor core structure deformation should still permit the insertion of a sufficient number of control rods to shut down the reactor.

The design of fuel rods should limit the vessel stress to less than 0.2 percent of the yield stress at maximum linear heat production (including designed excess power) in the early period of the operation and limit the vessel strain at maximum fuel consumption in the late period of the operation life.

The reactor core is situated below the center of the inlet and outlet connections of the pressure vessel so that in case main pipe rupture causes loss of water the reactor core is still submerged in the coolant. Antifracture support devices are installed at the bottom of the reactor core to prevent the reactor core from falling when the barrel is broken and to limit the axial drop distance so that the control rods in the guide tubes can still be quickly inserted into the core.

Leak detection devices are installed at the seals of the pressure vessel and leak guide tubes are installed between the sealing rings to monitor the temperature and pressure so that small leaks may be guided into the water circulation tank and prompt steps taken for large leaks. Special radiation monitor tubes are installed to monitor the pressure vessel material, material samples are taken out periodically to study changes and to insure the safety of the pressure vessel. To insure the smooth insertion and pulling out of the control rods for emergency shutdown within 1.8-2 seconds, the pressure vessel top cover and holddown device and the opening of the barrel must be accurately aligned and positioned. The pressure vessel is a cylindrical container with spherical or dish-like upper and lower seals. The upper seal may be disensembled and bolted to the cylinder body flange. The dimensions of the pressure vessel are listed in Table 4. The flange surface has "O" ring seals. The design pressure of the vessel is 1.1-1.25 times the working pressure, leaving a large safety margin. Foreign-made vessels have two self-tightening "O" rings, the first "O" ring does the sealing before it fails, and the second self-tightening "O" ring does the sealing after the first one fails. In the design of the Qinshan power plant, the first "O" ring is self-tightening and the second "O" ring is inflatable, based on a different design principle. The control rod drive mechanism is usually of the magnetic lift type. The lowering of the control rods relies on gravity and the raising of the control rods is done by a magnetic suction device. The speed of lowering and raising must meet design requirements so that the control rods may be inserted quickly into the core in case of accident and the design must also be convenient for dismantling and service. The [Robert E.] Ginna, Bezneou-1, and Mihama-1 all have four short rods too control the axial power shift caused by xenon oscillation. It was later realized that long control rods can also control the xenon oscillation. Therefore, most of today's power plants have done away with short control rods. The reactor core is generally equipped with a

Table 4. Design Parameters of the Pressure Vessel

Power station name	Chooz	Obrigheim	Ginna	Bezneou-1	Mihama-1	Qinshan
Material	A336	22NiMoGr37	SA302-B	Carbon steel	SA302 SA508	S271
Innerdiamter, m	3.21	3.29	3.35	3.30	3.30	3.34
Wall thickness, mm	230	160	177	100	229	194
Total height, m	11.2	9.8	11.92	11.7	10.7	10
Net weight, t	216	190		215		230

flux measurement device with a small fission chamber and a self-energy probe. With the exception of the aeroball system in the Obrigheim plant, all other stations use a translational calibration system for the monitor probe.

III. Main Features of the Power Device

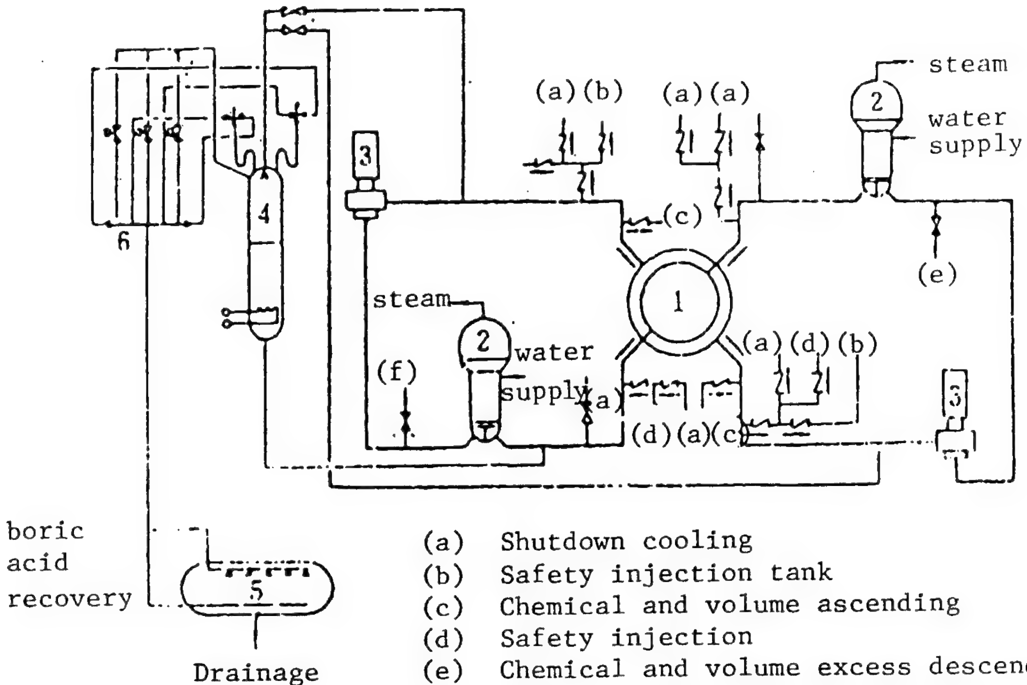
Compared with the power device of other larger PWR power plants, the power device of the 300 MW PWR power plant differs only in the number of main system loops and there are no fundamental differences. The main system of 300 MW - 600 MW power plants generally has two loops (see Fig. 1) but larger power plants may have three or four loops.

Each loop consists of a steam generator and a main circulating pump and is connected to the reactor through main pipes. The G.E. and B&W models use one steam generator and two main circulating pumps.) The main system also has a pressure stabilizer to keep the pressure fluctuation within the normal rated range for steady state and transient operating conditions. The main system also has an over-pressure protection device and a water level controller. Most PWR power plants are designed to track the electric load automatically within a range of 15-100 percent of the rated power and to accommodate ±5 percent per minute linear change and ±10 percent step change in full power without causing a shutdown or steam release or actuating the pressure-release value of the pressure stabilizer. When the turbine generator suddenly dumped the load or had an emergency shutdown, the steam release system may discharge 40 percent (or 100 percent) of the steam into the reactor and the primary return circuit so that the reactor will not have an emergency shutdown.

In addition to the main system, a PWR nuclear power plant also has a number of auxiliary systems (see Fig. 1).

According to their functions, auxiliary systems may be divided into the following categories: (1) Systems that insure the normal operation of the reactor and the primary circuit, such as chemical and volume control system, cooling water system, water drainage system, boric acid recovery system, shutdown cooling system and sampling system; (2) Auxiliary systems installed to

1. Reactor
2. Steam generator
3. Main pump
4. Pressure stabilizer
5. Pressure release tank
6. Steam release pipe assembly



(a) Shutdown cooling
(b) Safety injection tank
(c) Chemical and volume ascending
(d) Safety injection
(e) Chemical and volume excess descending
(f) Chemical and volume descending

Fig. 1. Primary Return System of a Nuclear Power Station

insure the power station safety and to prevent and contain water-loss incidents in the primary circuit, such as safety injection system, safety sprinkler system, safety vessel circulating air cooling system and hydrogen elimination system; and (3) Waste gas, liquid and solid treatment systems to reduce the amount of radioactive material released into the environment by the power station. In addition, almost all nuclear power stations have safety vessel isolation and fire fighting facilities.

The design principles of several important systems of China's Qinshan nuclear power plant are illustrated in Figs. 2, 3 and 4.

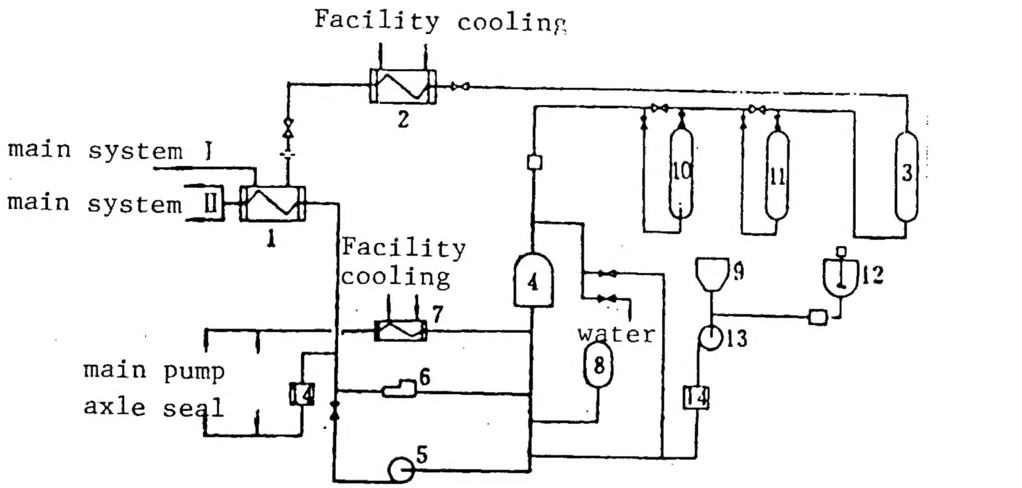


Fig. 2. Chemical and Volume Control System

Key:

1. Regeneration heat exchanger
2. Downflow heat exchanger
3. Purification ion exchanger
4. Volume control tank
5. Eccentric upflow pump
6. Reciprocating upflow pump
7. Sealed axle water return heat exchanger
8. Chemical replenishing tank
9. Boric acid storage tank
10. Boron-removing ion exchanger
11. Lithium-removing ion exchanger
12. Boric acid generation tank
13. Boron acid transport pump
14. Filter

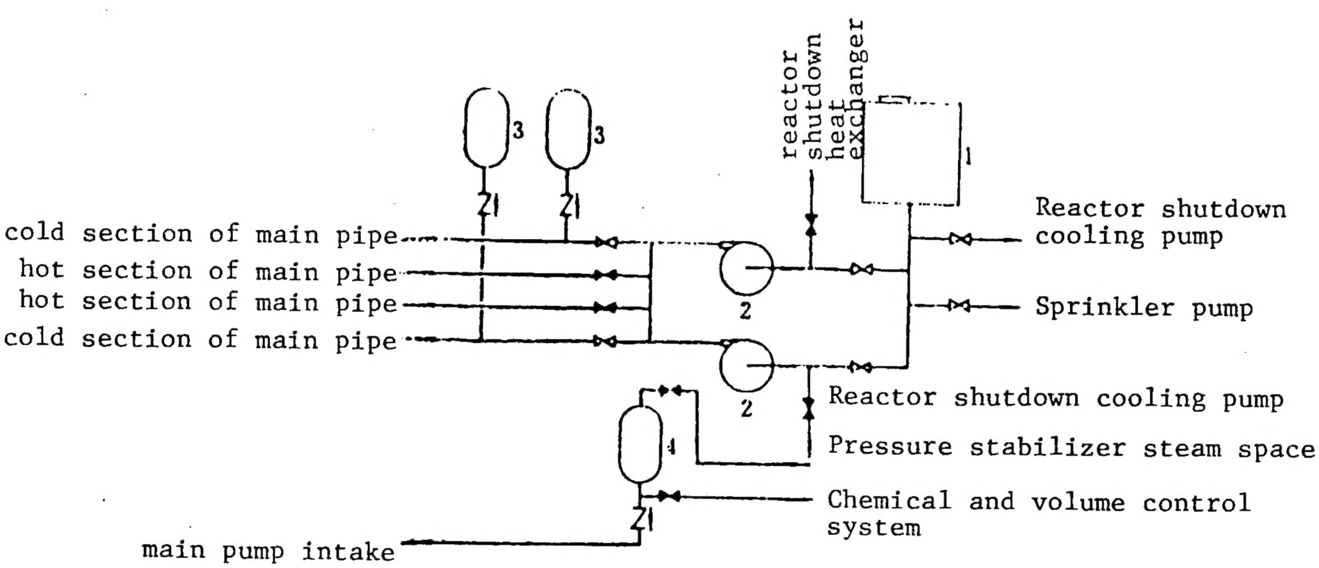


Fig. 3. Safety Injection System

Key:

1. Fuel change water tank
2. High-pressure safety injection pump
3. Safety injection tank
4. Emergency boric acid injection

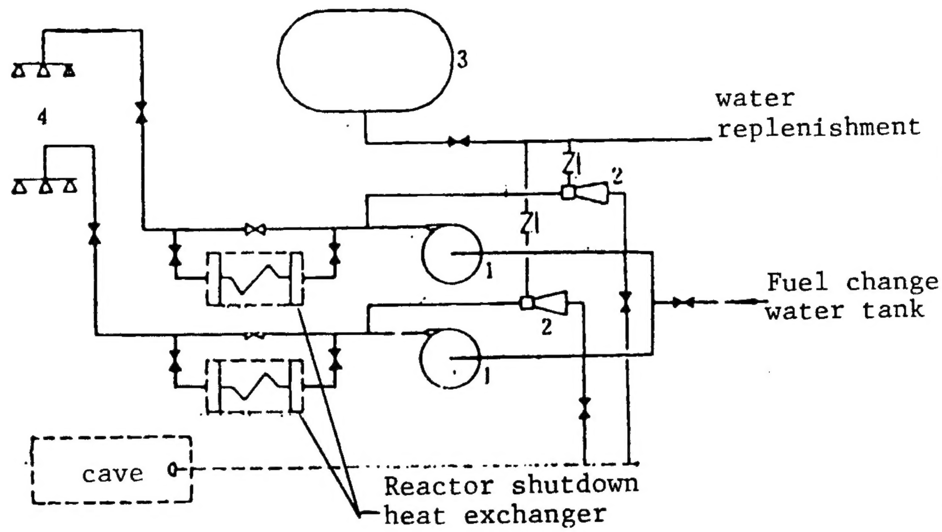


Fig. 4. Safety Sprinkler System

Key:
1. Sprinkler pump
2. NaOH sprayer
3. NaOH storage tank
4. Sprinkler head

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CSO: 8111/0243

BRIEFS

DAYA BAY PROJECT BEGINS--The construction of the first-phase project of the Guangdong nuclear power plant will formally begin on 2 April on the shore of Daya Bay in Shenzhen. The first-phase project includes the leveling of the site for the nuclear power plant as well as the land for project-related construction, the construction of highways, the installation of a power network for operations, and so on. At present, a contingent of more than 1,200 persons in charge of the construction as well as the equipment for the construction have been sent to the worksite. Various preparatory work is actively under way. [Text] [HK221450 Guangzhou Guangdong Provincial Service in Mandarin 0400 GMT 22 Mar 84]

CSO: 4013/149

LIAONING'S LARGEST METHANE FACILITY COMPLETED

Shenyang LIAONING RIBAO in Chinese 14 Jan 84 p 2

[Article by Li Dahong [2621 1129 3163]]

[Text] Liaoning's largest methane generating pit with an annual output of 1,300 cubic meters of methane and 30,000 tons of methane fertilizer was completed at Benxi at the end of October 1983. After more than 2 months of test runs, it has been approved as meeting all the technical specifications, and can be released for operation on time.

This large mechanized methane generating pit was designed by the China Agricultural Engineering Research and Design Institute. The project proper cost 550,000 yuan to build. The methane generating pit consists of a 1-stage $1000m^3$ fermentation tank, a 2-stage $300m^3$ fermentation tank supply storage, sediment and sludge storage, a heating system, and a mixing system. The entire production process is mechanized.

Once this methane generating pit begins operating, it will play a leading role at Benxi in improving public health, eliminating environmental pollution, providing a source of potent, non-toxic organic fertilizer, and opening up a source of energy. This pit, which collects over 80 tons of the city's night soil per day, helps improve public sanitation and destroy the "source of pollution." It produces 30,000 tons of non-toxic organic fertilizer a year, enough to fertilize 20,000 mu of gardens. The methane fertilizer contains 36 percent organic matter, three times that of ordinary farm fertilizer. If the 1,300 cubic meters of methane it generates per year were used as household fuel, it would be enough to meet the needs of 600 households. Used as transportation fuel, it would save the city nearly 20 tons of gasoline per year.

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END